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AGRICULTURAL EXPERIMENT STATION.

SHADE TREES,

CHARACTERISTICS, ADAPTATION, DISEASES AND CARE.

Each

G. E. Stone

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CONTENTS.

CONTENTS.

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DEPARTMENT OF BOTANY.

SHADE TREES, CHARACTERISTICS, ADAPTATION, DISEASES AND CARE.

BY GEORGE E. STONE.

INTRODUCTION.

The general interest in shade trees, particularly in the eastern States, well illustrated by the amount of money expended upon them and the many questions asked concerning their welfare, has created a demand for a brief, practical bulletin covering the various questions relative to shade trees and their management. Bulletin No. 125, issued in 1908 by the Massachusetts Agricultural Experiment Station and the Massachusetts Forestry Association, covered the subject in a general way, but the publication is now exhausted.

Shade trees add greatly to the desirability of a community as a place of residence, and their æsthetic value cannot be estimated in dollars and cents. It is no exaggeration to say that the complete destruction of all the trees and shrubbery would reduce the valuation of some cities and towns very materially.

Trees also possess a utilitarian value which is recognized by the courts, and for the careless destruction of street trees the abutter is entitled to compensation. A street tree adds value to real estate in the same way that a sidewalk or curbing does, but while the sidewalk and curbing may deteriorate, a tree increases in value for many years; for example, a tree originally costing $2 to set out may be worth $150 in sixty years, which is equivalent to $7\frac{1}{2}$ per cent. compound interest on the investment.

Too much emphasis cannot be laid upon the care of shade trees. In common with crops they give the best results under cultivation, but unfortunately the best conditions do not always exist. Trees grow fairly well on lawns, however, especially when the lawn is occasionally fertilized. Conditions on congested streets are quite different. Many of the trees on our village greens, where often little attention is given to their care, show neglect and need of better treatment. In many places they have

been growing for years in sod to which no fertilizer has been applied and a hay crop removed annually, and in such cases one year's use of a plow and harrow, together with manuring and some kind of cropping, would work wonders in restoring them.

In applying remedies to trees it is well to be on the conservative side, since it is a very easy matter to cause them serious injury. The different spraying mixtures, etc., recommended for trees are not always to be depended upon, and many trees are injured by their use; hence a word of caution is not out of place. Unfortunately, at the present time it is necessary to be on the watch for fake "tree doctors" who often do more damage to trees than good. This class of so-called "tree experts" has greatly increased within the last few years, and in some localities has become a nuisance. The "tree faker" is not only ignorant and incompetent, but is dishonest and a "divine right" fiend. There is another class of workers who may be ignorant, but honest; and still another class possessing some intelligent ideas as to tree work and a desire to be conscientious, but they fail to produce the best results. The men who possess sufficient technical knowledge and skill to undertake work on trees are comparatively rare, although fortunately there are a few competent firms and professional men who are capable of giving advice in regard to the treatment of trees.

The tree warden should be, and often is, a man of intelligence and common sense, and one to be called upon for advice pertaining to trees.

Requirements of Shade Trees.

As a rule, those trees should be planted which are known to thrive well in the particular environment under consideration. The fact that a tree does not grow naturally in one locality is no evidence that it will not thrive in some other, and it is well known that species of trees peculiar to wet places will grow in those inclined to be dry; but there is a limit to the adaptability of trees as regards their best growth and development which should be taken into consideration. A species naturally adapted to a wet environment is more likely to suffer from the effects of extreme meteorological conditions when planted in a dry situation than one normal to such places. The nature of the soil environment is, therefore, important; and there are many other factors which enter very largely into the problem of selection and planting of shade trees. Naturally there is a considerable difference of opinion in regard to what are the best trees to plant. It is important, therefore, to choose those species which are best adapted to the conditions under which they are to be grown, all trees having their weaknesses and defects, and perfection being no more common to trees than to the human race. The past decade has been characterized by extremely erratic conditions, such as unprecedented drought during the growing season, and severe winters, both of which have been responsible for so much deterioration of trees that the question of selecting resistant types has been a vexing one. Moreover, the presence

of destructive insects and fungous pests, which heretofore have not been troublesome, has rendered the problem still more perplexing.

Some of the factors which enter into the problem of selecting species and varieties for shade trees are the following: —

Adaptability to Climatic Conditions.

One of the first requisites in selecting a tree for street planting is a knowledge of its climatic requirements. Many species of trees are likely to suffer from extreme meteorological conditions, and even species indigenous to a certain region may prove a failure when planted in a city or town as shade or street trees. There are also certain species which have their limitations as regards climate, such as some Japanese varieties, and in planting this should be taken into account. Under adaptability to climatic conditions is included the ability of a species to withstand the detrimental effects resulting from heat and cold, wind, snow and ice, atmosphere and soil moisture and light intensity.

Hardiness and Resistance.

Hardiness and resistance are the capacity of a species to withstand extremes of climate and the more or less abnormal and severe conditions of the particular environment in which it may be placed. These may arise in part from the peculiar atmospheric and soil conditions which are characteristic of congested settlements where the soil has been made from various types of refuse, or may be due to the presence of large manufacturing establishments.

Configuration and Conformity.

The shape or form of a species, as well as its conformity to its environment, is essential. Wide avenues demand different species from narrow avenues; and the habit of branching, root development, height, spread of the crown and general symmetry of the tree should be considered.

Longevity.

The age which a species is capable of attaining is important in its selection for planting, and while short-lived trees may have their use in certain places for temporary growth, a longer-lived variety should be selected for permanent effects. While the causes underlying senescence and rejuvenescence are hereditary in individuals, the life and usefulness of a tree may be prolonged by treatment, and its configuration greatly modified. Some trees, such as the apple, are readily rejuvenated, while others respond very poorly to treatment.

Rapidity of Growth.

The growth of trees in general is quite variable. Even individuals of the same species are different in this respect. Much also depends on environment in the growth of trees. The modern tendency in tree plant-

ing is to secure quick results; hence during recent years much use has been made on streets of the Carolina poplar and soft maples instead of the better and more slowly growing species, such as rock maples, elms and oaks. Excepting a few rapidly growing trees like the poplars and others, there is not much difference in the rapidity of growth of different species if they are given ideal conditions. While the production of quick growths is quite legitimate in planting, the idea of a permanent effect should not be lost sight of; and it is possible to accomplish both of these results by methods of planting.

Shade Production.

The amount of shade produced by any kind of tree depends on the shape of the crown and the density of the foliage. The more rapidly a tree grows the more quickly shade is secured. The shape of the crown varies with different species, but may be readily modified in such trees as the poplar by pruning. Shade constitutes the important feature in street trees, and is perhaps the most essential qualification of an ornamental tree.

Root Peculiarities or Habits.

The nature of the root development is an important factor in the selection of shade trees. Such trees as the maple and elm possess large, spreading root systems which are generally interfered with by street repairs, excavations, etc., while some other trees more restricted in their root development more often escape injury. The tendency of the roots of some trees to penetrate drainage and sewer pipes is an objectionable feature, as is also the upheaval of sidewalks, dislocation of curbings, etc., which result from the root development of certain species of street trees.

Neatness.

Much objection is often made to species like poplars, horse-chestnuts, etc., that produce litter, which requires frequent cleaning up. Some fruits, such as the mulberry, are mucilaginous and often become dangerous on sidewalks. Nut trees are also likely to be objectionable on residential streets because of the nature of their fruit and the liability of injury to the trees when it is gathered. It should also be mentioned that certain trees — such as the staminate form of Ailanthus — which emit disagreeable and irritating odors are undesirable.

Æsthetic Value.

The modern civic requirements in street planting demand not only the selection of healthy and vigorous trees and their general adaptation to the physical conditions surrounding them, but the consideration of beauty, taste and general arrangement as regards surroundings and conformity to an intelligent treatment, or, in other words, the æsthetic and landscape features. At the present time city streets are often provided with

parkways which are planted with shrubbery and trees, and consequently both the nature of the species to be planted and the arrangement of the individual trees should be studied in order to have them conform with the general surroundings. This point of view of the matter is important and should not be lost sight of, since the æsthetic arrangement of streets and avenues adds to the value of adjoining estates in general.

Susceptibility to Insect Pests and Diseases.

Injurious fungi and insects are indigenous to every community, and many new pests are constantly being introduced, so that it is impossible to draw definite conclusions as regards immunity or susceptibility of any species of shade trees or ornamental shrubbery to those organisms. Judgment upon the probability of injury in any particular case must be based upon individual experience. There are scarcely any shade trees, however, which are not regularly affected by certain insects and fungi, and they are, moreover, subject to local and sporadic attacks. Trees which are exceptionally susceptible to insects, fungi and other injurious factors should be sparingly planted.

Commercial Importance.

Street trees are, as a rule, not planted for any commercial consideration, and the commercial idea should always be a secondary one. It happens, however, that sometimes the nature of the growth along country roadsides is such that thinning may advantageously be done, much good timber thus being obtained by the abutter; but this thinning should be done with discretion. There are also quite a few trees, such as the basswood and tulip, for example, and many shrubs, that are valuable as honey species, and their utilitarian value in this respect should not prevent their selection for planting. In European countries fruit trees are often planted along the country roadsides, where they not only serve ornamental purposes, but have a distinct commercial value in the production of fruit.

Street and Roadside Trees.

American Elm (*Ulmus americana*). — This is one of the most widely planted trees in New England, where it reaches its height of perfection. It is generally symmetrical in outline, attaining a good age, one hundred to three hundred years, and often large dimensions. The best developed types are majestic and more beautiful than any other tree known. According to Olmsted Brothers, landscape gardeners, "there is no other sort of tree which gives the effect of a lofty, over-arching canopy of foliage, which observation of village greens leads us to believe is the effect mostly to be desired." It is difficult for an elm to thrive on dry, gravelly soil, and when located in such situations it is inclined to be lanky, develops slowly, and is unhealthy in appearance. It is best suited to a fertile, more or less moist soil where fine sand and silts predominate, and is well adapted

to lawns and roadsides, but not at all to mowings. The high branching habits of this tree render it the best type we have for streets on which there are numerous wires. In recent years it has become infested with such insects as the elm-leaf beetle, and most disastrously by the leopard moth. It has suffered more of late from the effect of drought than any other tree, and extreme cold has affected its root system to a considerable extent. These defects have been the means of discouraging its planting. The elm has a habit of occasionally shedding its leaves and twigs, and is sometimes affected by a leaf fungus (*Dothidella*).

FIG. 1.—The Lancaster elm.

SLIPPERY ELM (*Ulmus fulva*).—Occasionally the slippery elm is planted by mistake for the American elm. It is, however, a much smaller and inferior tree.

ENGLISH ELM (*Ulmus campestris*).—This tree, which attains a large size, is a handsome species, and was formerly planted more extensively, at least in certain localities. It is, however, more susceptible to the elm-leaf beetle than our native species. Other elms which may be mentioned here are the Scotch elm (*U. montana*), which is occasionally seen; the Cork elm (*U. racemosa*), a tree of fairly good size with a corky bark and of slow growth; and the Japanese elm (*U. japonica*), a handsome, symmetrical tree of rapid growth, little known in America. Although affected to some extent by the elm-leaf beetle, this elm gives promise of becoming a valuable shade tree.

FIG. 2.—Type of feathered elm.

ROCK MAPLE (*Acer saccharum*).—The maples as a whole have been more extensively used for street planting than trees of any other group. The rock maple, like the elm, has been extensively employed as an ornamental tree; indeed, there is no species that has been used more widely for lawns and avenues than the rock maple. It is one of our handsomest trees, being characterized by unusual symmetry and dense foliage. It

develops rapidly under good soil conditions, and occasionally will attain a diameter of 12 inches in fifteen or sixteen years. In some situations it grows to be an enormous tree, and quite often attains an age of one hundred and fifty years or more. The rock maple is sometimes affected with a leaf spot, and is more susceptible than any other tree to sun scorch and bronzing of the foliage. It is also quite susceptible to frost cracks. During the past five or six years this tree has suffered much from extreme drought, and as a result many staghead specimens are to be seen.

FIG. 3 — Rock maple growing in pasture.

WHITE OR SILVER MAPLE (*Acer saccharinum*). — This species is not equal to the rock maple, either from the point of view of durability or of beauty, and it is too commonly disfigured by ice and winds. It grows very rapidly, and in southern New England, where magnificent specimens may occasionally be seen, it attains a great size. It is planted on avenues and lawns to a very large extent, but the drooping habit of its branches, together with its liability to injury, affect its value somewhat for street planting. In most situations its real value consists in its rapid growth and ability to produce quick shade effects. It is attacked by a leaf spot fungus (*Rhytisma*) which, however, does little harm.

FIG. 4. — Avenue of elms planted close.

RED MAPLE (*Acer rubrum*). — The red maple is a tree of rapid growth, well adapted to swamps and fairly moist places. It has been planted quite extensively on streets, often, no doubt, in mistake for the rock maple. It develops large branches, usually rather low, which should be pruned at the

time of transplanting. The foliage of the red maple is inferior to that of the rock maple both as regards color and density. This species has suffered much from drought and winterkilling of roots, which is characterized by a "staghead" condition. The leaves are often conspicuously spotted by the fungus *Rhytisma*.

Norway Maple (*Acer platanoides*). — The Norway maple is a wide-spreading tree, with large leaves which give a dense shade. It is well suited to lawn planting, and is highly regarded for streets and roadsides. The Norway maple is perhaps at the present day one of the most extensively planted street trees, especially in cities. It is a rapidly growing tree, and, at least when young, is very symmetrical and well adapted to city conditions. However, whether the Norway maple will in the long run prove equal to the rock maple as a shade tree under severe city conditions is a question. When planted in unfavorable locations it is sometimes badly affected with sun scald, and the small terminal branches sometimes winterkill and become affected with the cinnamon colored fungus *Nectria*.

White Oak (*Quercus alba*). — This species is seldom planted as a street tree because of its slow growth. Its habits of branching are not always well adapted to streets, although it makes magnificent individual specimens for lawns and roadsides. It is occasionally affected by a leaf fungus (*Glœosporium*) and by various insects, and is one of the preferred food plants of the gypsy moth.

Fig. 5. — Specimen of red oak.

Red Oak (*Quercus rubra*). — In former years little consideration was given to the red oak as a street or ornamental tree, although recently it has received much well-deserved attention. At present it ranks among the first as a species possessing all the required qualifications for planting. The growth of the red oak is quite rapid; it is symmetrical and clean in appearance and exceptionally free from injury resulting from insects, fungi and other causes. It is adapted to a variety of soils, quite easily transplanted, and should be more extensively used as a street and country roadside tree.

Black or Yellow Oak (*Quercus velutina*). — This oak is often found associated with the red oak, but will tolerate much drier soils. It does

possess, however, the qualifications of the former species, and is best adapted to country roadsides.

Scarlet Oak (*Quercus coccinea*). — The scarlet oak is one of the most beautiful oaks in New England. It is adapted to the driest and poorest of soils, often being associated with the black or yellow oak. It is a tree of slow growth, and on this account has been planted very sparingly in the past. Recently, however, it has come to be more appreciated. The beautiful scarlet foliage, characteristic of this tree in the fall, is much admired. It is well suited to dry, gravelly soil where other trees, such as the elm, will not thrive. In some cases it has been effectively alternated on country roadsides with some tree of rapid growth, as the Carolina poplar, the poplars being removed when the oaks have reached a fair size. The scarlet oak is worthy of much more attention as a shade tree than it has received, especially for suburban streets and country roadsides.

Pin Oak (*Quercus palustris*). — The pin oak has its northern limit in Massachusetts, and in the Connecticut valley, where it is found quite abundantly, it becomes a handsome tree. It naturally grows in rich, moist soil and often in water, and appears not to tolerate too dry conditions. The symmetrical, triangular or pyramidal shape of the crown and its drooping branches give it an individuality distinct from other trees. The growth characteristic of this tree in New England appears to be somewhat different from that further south, as is the case with most trees. In the north it appears to retain its youthful form longer than elsewhere. It should be planted in soil having a texture capable of holding moisture, and the addition of organic matter is advisable. Under desirable soil conditions the pin oak attains a diameter of 6 or 7 inches in nine or ten years. It is well adapted to narrow streets, and especially to lawns and parks. The characteristic drooping habit of its limbs necessitates careful and high pruning when planted on streets. The pin oak resembles the red oak in being relatively free from troubles induced by insects, fungi, etc., and may be considered one of our most promising shade trees.

Mossy Cup Oak (*Quercus macrocarpa*) and swamp white oak (*Quercus bicolor*) are sometimes planted on country roadsides. The latter, which makes slow growth, is adapted to wet places.

Basswood or American Linden (*Tilia americana*) is a native of New England, but is seldom planted on streets, although it is adapted to certain locations. It is a beautiful tree — with bright green foliage, graceful and symmetrical when young, but when planted too closely it loses its lower limbs and is inclined to early deterioration.

European Linden (*Tilia sp.*). — The linden has been much planted as a shade tree, and is a good tree when young and vigorous. The tree is not as a rule long lived, and it is often subject to sun scald and frost cracks from which it deteriorates rapidly. It is also likely to be affected with sooty mold, which follows the honeydew secretions of aphids. This materially affects the appearance of the tree. There are several species

of linden under cultivation which possess distinctive characteristics, and these have been sadly confused by nurserymen. The two species most commonly planted are *T. vulgaris* and *T. platyphyllos*. According to H. J. Koehler,[1] *T. vulgaris* is one of the best trees to plant, while *T. platyphyllos* is one of the worst. Excellent types of lindens may be seen in the Arnold Arboretum, some of which will perhaps eventually prove superior to either of the above species.

FIG. 6.— Avenue of lindens.

HORSE-CHESTNUT (*Œsculus hyppocastanum*). — The horse-chestnut, like the linden, was introduced from Europe, and has been much planted on streets. It grows rapidly, but it is not, as a rule, a long-lived tree. It is affected by a leaf-spot fungus (*Phyllosticta*), sometimes losing much of its foliage on this account, and often many of the twigs are winterkilled and affected with *Nectria*. It is also susceptible to sun scald and frost crack, and the amount of litter produced by the fruit is somewhat objectionable. The red-flowering horse-chestnut is occasionally planted and is preferred by many.

SYCAMORE (*Platanus occidentalis*). — Fine individual specimens of our native sycamore may often be seen on lawns and roadsides in New England, but it has been used in the past to a limited extent for avenue effects. The sycamore has a wide range, being confined in the north to river valleys. It naturally prefers a rich soil, and when transplanted under good conditions it attains a large size. The sycamore will endure any amount of pruning, and can be adapted to any street, even the busiest thoroughfares. Much more use is made of the sycamore than formerly, especially in cities, and the oriental species (*P. orientalis*) is also much employed. The sycamore is severely affected with a leaf-spot fungus (*Glœosporium*) which often causes serious defoliation. The younger twigs sometimes winterkill badly, but the tree will stand a great deal of hard usage and mutilation.

AILANTHUS (*Ailanthus glandulosa*). — The Ailanthus may be termed a "scavenger tree," as it will grow anywhere and will endure more trying conditions than any other tree. It is frequently found growing along railroad embankments, on dumping grounds, — in fact, no conditions seem too severe for it. It is used to some extent as a street tree, and excellent individual specimens may be seen here and there. Where quick effects are desired it is worthy of consideration. The Ailanthus, which is a native

[1] Landscape Architecture, July, 1915.

of China, is often termed the "tree of heaven," concerning which Dr. Asa Gray has well remarked that its blossoms are "redolent of anything but airs from heaven." To obviate the disagreeable odors arising from this species only the pistillate trees should be used for planting, the disagreeable odor being given off by the male or staminate flowers, which are often borne on separate trees. The Ailanthus apparently tolerates obnoxious atmospheric gases better than most other trees.

Tulip Tree (*Liriodendron tulipifera*). — This is an excellent tree for roadsides, although it is not very much planted. It is probably better

Fig. 7. — Avenue of pin oaks transplanted seven years in 40-foot avenue.

suited to lawns and country streets than to the hard usage it might receive on city streets. The tulip is indigenous to different parts of New England. It is a difficult tree to transplant successfully, and this may account for its not having been more extensively employed. This species attains a large size, developing a large symmetrical crown with handsome foliage. It requires good, well-drained soil, and is best adapted to wide avenues provided with generous tree belts. The leaves sometimes become badly spotted from attacks of insects and fungi, but the loss in transplanting and its lack of adaptability to certain situations are the chief objections to its use as a street tree, at least in the north.

White Ash (*Fraxinus americana*). — This ash is commonly seen on streets. It was formerly planted more extensively than at present. Our measurements of a number of white ash trees which had grown in good

soil and which were twenty-two years old showed an average diameter of 16 inches, while others grown in dry, gravelly soil attained an average diameter of only 12 inches during the same time. The white ash develops a widespreading top, and is a fairly desirable shade tree, although in too dry locations it may become affected by borers and scale insects. It has suffered much in recent years from drought, winterkilling and in some locations from a rust (*Æcidium fraxini*). Other species of ashes, like the black ash, are occasionally planted accidentally for the white ash.

Cucumber Tree or Magnolia (*Magnolia acuminata*) has been highly recommended by some authorities for roadside planting. It has been employed extensively as an ornamental tree, but no attempt so far as we know has been made to utilize it as a street tree in the north.

Sweet Gum (*Liquidambar styraciflua*) is a native farther south, Massachusetts appearing to be a little too far north for its best development. At any rate we have observed no satisfactory growth of this species in this section. It is subject to winterkilling and frost cracks in the north.

Ginkgo (*Ginkgo biloba*), a Japanese species, is occasionally seen on lawns, and forms a beautiful avenue on the agricultural grounds at Washington, D. C. Well-developed individual specimens of Ginkgo may be observed here and there in New England, and this tree has been used to some extent for street planting. It is adapted to a wide variety of soils, and is remarkably free from diseases. It develops a narrow cylindrical or conical crown, which adapts itself to narrow streets. This species is undoubtedly better adapted to planting farther south than in New England; nevertheless, it possesses many qualifications as a desirable street tree, and should be utilized for this purpose in suitable locations.

Carolina Poplar (*Populus deltoides*), which is now quite extensively planted, is one of the most rapidly growing species, and is a valuable tree for producing quick effects. The Carolina poplar is especially useful to fill in between trees of slow growth but of more desirable types. Good avenues of this species may be seen about Boston in the metropolitan park system, where the trees have been cut back to form a compact head. This tree, however, is subject to various troubles, and is short lived. Two other native species of poplar, *i.e.*, *P. grandidentata* and *P. tremuloides*, are common, but have no value for planting.

Black or Italian Poplar (*Populus nigra*). — This species has been planted somewhat as a lawn and avenue tree. It grows even more rapidly than the Carolina poplar, and possesses similar characteristics. It is affected by a rust (*Melampsora populina*) which sometimes causes much defoliation.

Lombardy Poplar (*P. nigra* var. *italica*) has been planted sparingly for more than a century in New England, and has come into wider use of late. It is used somewhat on narrow avenues, although on account of its ascending and close-branching habit of growth it does not furnish much shade, and is, moreover, too stiff and conventional in appearance for most places. The white or silver-leaved poplar (*P. alba*) and the

balm of Gilead (*P. candicans*) have been planted occasionally on streets and near dwellings for many years. The former, which is characterized by its silvery leaves, grows to a large, widespreading tree.

Black Locust (*Robinia pseudacacia*). — The black locust is one of our most rapidly growing trees, and while it is spontaneous here it is native farther south than New England. It adapts itself to severe conditions, and withstands obnoxious atmospheric gases better than any other tree, but it is so attacked by borers at times as to render its use as a street tree of little account. It is a valuable honey tree, and may be employed as a hedgerow or screen near dwellings, and near smelters and large manufacturing plants where noxious gases prevail.

Honey Locust (*Gleditschia triacanthos*) is a tree reaching large dimensions and provided with stout thorns. It is sometimes used in planting.

Chestnut (*Castanea dentata*) frequently grows profusely along roadsides and at times on lawns. It is not adapted to street planting on account of the litter accompanying fruiting, and its rapid destruction from the blight at present renders this species useless for any purpose.

Hackberry (*Celtis occidentalis*), which is closely related to our elm, is found sparingly in some of our river valleys, and occasionally met with on streets side by side with the elm. During recent years some have advised planting this tree instead of the elm, as it is said to be less susceptible to insects, particularly the elm-leaf beetle. It is a much inferior tree, however, to the elm.

Hardy Catalpa (*Catalpa speciosa*) is more at home in the west, although used here as an ornamental tree. With us it does not sustain its western reputation for growth, and according to our observations it has little or no value as a street tree in most northern sections.

Some of the willows are employed effectively for planting near marshes and low, swampy grounds. They afford protection to roadsides and are valuable as screens to unsightly places. The laurel-leaved or bay willow (*Salix pentandra*), which attains a height of 20 or 25 feet, is used on country roadsides and sometimes on lawns. It has dark green, glossy foliage. It is adapted to hedges and thrives well near the seashore. The weeping willow (*Salix babylonica*) and a few other forms are planted for ornamentation and shade-producing effects.

Fine individual specimens of the black walnut (*Juglans nigra*), a tree sparingly native in New England, may be seen on lawns, but according to our observations on the results of planting this species on roadsides it appears to be a failure as a shade tree.

Box elder (*Negundo aceroides*) is occasionally grown near dwellings, but is not a satisfactory street tree under New England conditions.

The various conifers may be used under suitable conditions, such as on country roadsides, and some use is made of them for this purpose. The white pine and Norway spruce are sometimes planted along roadsides, and are especially valuable as wind breaks. The European larch, Scotch and Austrian pines, as well as our superior red pine, may be em-

ployed advantageously for the same purpose. The shade produced by roadside planting is beneficial to a roadbed, as it prevents the rapid evaporation of water from the surface, and has a similar effect in this respect to some chemical road dressings in controlling dust. Moreover, a roadbed under such conditions retains its surface better than one constantly exposed to the sun, and there is less trouble from drifting snow.

Since new plant material is being constantly introduced into the United States from foreign countries there is a likelihood of some new and desirable species of shade trees becoming available in the future.

FIG. 8. — Street with ideal tree belt. (See Fig. 13.)

The large and unrivaled collection of trees to be seen in the Arnold Arboretum, Jamaica Plain, Mass., furnishes good examples for consideration. According to the most experienced planters the trees best suited for street purposes in New England are as follows: *elm, rock, white, red* and *Norway maples, red, scarlet* and *pin oaks, basswood, tulip tree, Ginkgo, cucumber tree, hackberry, English elm, horse-chestnut, sycamore* and *white ash.*

For wide avenues large species such as the *elm, rock* and *white maples, tulip tree, sycamore,* etc., are recommended; and for narrow streets the *pin oak, Norway maple, sweet gum, catalpa, Ginkgo* and *horse-chestnut.* For severe conditions the *English elm, horse-chestnut, linden* and *Ailanthus* are considered the most desirable species. No fixed rule, however, can be laid down as regards the use of the different species of trees for wide, medium or narrow streets, as different effects in planting are often sought. Indeed, one of the most serious defects in planting of all kinds is the lack of originality. Imitation in methods, the constant use of certain species and varieties, and the extreme conventional effects often produced become wearisome, while the marked diversity of Nature's planting, always resourceful in producing harmonious effects, never becomes tiresome. In general, however, the large type of shade tree, like the elm, maple and others, should be used on wide streets, and those having a more pyram-

idal type of crown are better suited for narrow avenues. In considering the problem of the selection of shade trees it should be borne in mind that there exists much variation in their habit of growth due to the conditions under which they are grown, and what may do well in one location will be more or less of a failure in another. There exists a marked variation in the growth of trees, even of the same species, in a restricted territory, and one can find much variation in their mode of development, such as habit of branching, size and color of leaves, height to which they grow, and age to which they attain, — in short, their general configuration. The elm grows quite differently in the north than in the south, and even in New England many specific types may be met which are characteristic of special localities. Hence, in order to secure the best type of elm trees for planting it would be well worth while to obtain them from localities which develop the best branching habits, such, for example, as the Berkshire region in Massachusetts. There are some species that are indigenous to the south which grow larger and do better in their native environment than in the north.

Such trees as the magnolia, catalpa, Kentucky coffee tree, box elder, persimmon and mock orange are much better adapted to the south than the north, and consequently are of much more value as ornamental trees in that section.

What shall we plant?

Perhaps the most perplexing question relating to shade trees, at least during the last decade, is "What shall we plant?" There has probably never been a period within the memory of living man during which such severe conditions for vegetation have prevailed, especially in the eastern States, as in the past few years. Meteorological records for many years back would undoubtedly fail to show similar conditions, and even if they did they would be of little value, owing to the fact that there are important factors other than those recorded by meteorological observations which greatly affect vegetation and its mode of development. The growth of trees themselves, as well as local variations in a restricted environment, constitute a record of general meteorological phenomena. Since trees live a century or more, these data are valuable.

Fig. 9. — Showing deterioration of elms, largely due to the leopard moth.

Considering the amount of deterioration in trees during recent years many tree wardens and city foresters have been in a quandary as to what species to plant. But there is reason to believe that these severe conditions are past, and it may be a century before they occur again. One of our most valuable and beautiful species, *i.e.*, the elm, has been practically abandoned as a shade tree in some places owing to its rapid and general deterioration. There are many other species that have been affected in a similar manner to the elm, although perhaps not so seriously. Notwithstanding the fact that some trees have suffered particularly from various causes, we believe that these should still be utilized for planting, their æsthetic and other qualifications being such that they cannot be dispensed with. Moreover, affection by insects and fungous diseases must not always be considered too seriously in judging the value of a species, since control of many of them is possible with the use of modern methods. It should be borne in mind that many of the pests are secondary or are subservient to other causes.

The European cut-leaf birch, which has been dying off in wholesale fashion of late, is always associated with borers, which are considered a specific cause of the dying of this tree. Quite the reverse is true, however, as the borers are secondary to drought injury. In fact, every serious drought period affects the cut-leaf birch in this manner; the roots become dried out and the tree falls a prey to borers. Borers in trees may not always occur secondarily to some other cause, but it is extremely rare to find healthy trees affected with borers. As soon as a tree becomes slightly abnormal from any cause, infection follows. Even the slightest poisoning from gas or injury to the roots by drought or winterkilling is sufficient cause for weakening the trees, and borers and other insects follow as a secondary cause. There is no reason, however, why the European cut-leaf birch or other trees should fall a prey to borers if properly planted in a suitable soil and well supplied with water during drought periods, preferably by subirrigation methods.

The elm has suffered from elm-leaf beetle to some extent, although rarely is one found dying from this cause. Many elms have been practically ruined by the leopard moth. However, it can be stated as a general principle that weak trees, or those that are under more or less abnormal conditions, are more likely to be affected by insects and fungi than strong, healthy, vigorous ones. In our opinion this holds true for the elm-leaf beetle infestation, and some of our most careful observers regard the leopard moth as secondary to other causes. The so-called "chestnut blight" is held by some competent pathologists to be secondary to some other cause or deteriorating factors common to the chestnut. In support of this idea it is known that numerous chestnut trees have been dying the last few years, from New England to Tennessee, which are not and never have been affected with the blight fungus.

The most important lesson to be learned from the behavior of shade trees during the past years of trying experience is that we must give more

attention to the specific requirements of the different species of shade trees, particularly as regards soil conditions. Species which cannot tolerate drought or the slightest soil desiccation should never be planted in sandy or gravelly soils possessing little water-retaining capacity; hence care should be taken in dry situations in eliminating those species which naturally grow in wet places. Neither should species that are adapted to dry soil be planted in wet places. The more extensive use of loam or soil containing a considerable amount of organic matter is needed in tree planting.

In conclusion it may be stated that the problems associated with tree planting during the last decade do not constitute a reliable criterion of the specific value of any species, since the same combination of conditions is not likely to occur in a century. We believe, therefore, that any one is justified in planting the much condemned elm, at least in country towns, where atmospheric conditions are much more favorable than in cities, and where the leopard moth is not so destructive.

Rapidity of Growth of Trees.

The variation in the growth of trees, due to the influence of many different factors, is quite marked, and even when trees of the same age are growing side by side great difference in the size and development are noticeable. A chestnut tree under certain conditions will attain a diameter of 3 feet in fifty-six years, while another may require one hundred and fifty years to reach a diameter of 18 inches. The average diameter of 20 white ash trees measured by us was 16 inches in twenty years; and Italian poplars will occasionally grow 26 inches in the same length of time. The Carolina poplar will reach a diameter of 30 inches in fifteen years, which almost equals the growth of the eucalyptus in California. We have observed pin oaks that grew 18 inches in diameter in twenty years. The average diameter of 16 elm trees thirty years old was 17 inches. In another instance a similar number of elm trees attained an average diameter of 20 inches 4 feet from the ground in forty years. Recent measurements have shown that the average diameter growth of the thirty-year-old elm trees for a period of seven years was 3 inches, while that of the forty-year-old trees during the same period was 4½ inches. It is not uncommon to find elms that have grown 3 feet in diameter in fifty years, or 4 feet in seventy years. An elm one hundred and thirty-one years old had a height of 110 feet, and a diameter of 6 feet at the base. On the other hand, many instances might be mentioned where trees have made very slow growth. Some elms, for example, showed a growth of only 11 inches in diameter in fifty years, and a white oak one hundred and thirty-two years old reached a diameter of 16 inches. Rock maples grow fairly rapidly in good soils, but we know of instances in which they have made only 6 or 8 inches growth in diameter in sixty years. Species accustomed to swamps, such as the white cedar and black spruce, grow quite

slowly, the latter not growing more than 5 inches in diameter in seventy years.

To obtain the approximate growth of trees in any particular locality would require measurements of a very large number of specimens. The age of trees may be obtained by counting the annual rings of felled trees, or by cores taken from the trunk of living trees, while the age of conifers and others may be estimated by the number of internodes formed. There is often a wide difference of opinion as regards the age of living trees, as the total leaf area is seldom taken into consideration. Since trees acquire

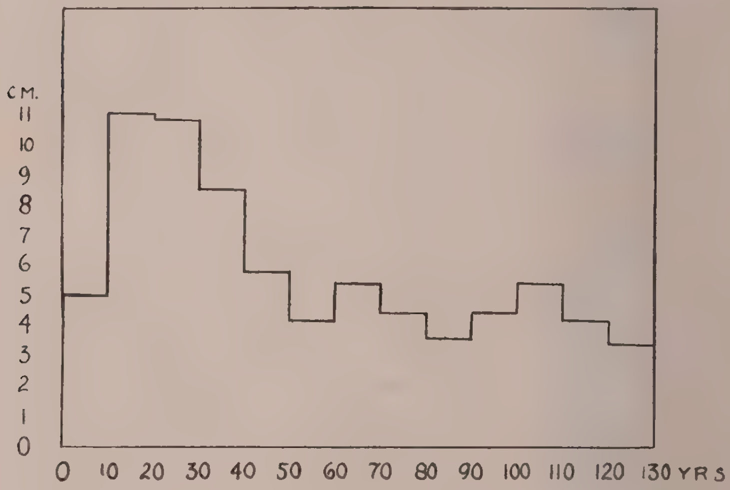

FIG. 10.—Grand period of growth (cross-section measurements) of an elm tree (*Ulmus americana* L.) in centimeters and decades. The maximum growth occurred between the tenth and thirtieth years, followed by a gradual decrease. From the nature of the curve we may conclude that if the tree had survived under normal conditions it was capable of developing for one hundred years more.

practically all their structural material from the air by means of the chemical processes going on in the leaves, it follows that those possessing a large total leaf area grow much faster than those with a smaller leaf area. A well-branched tree in the open will, therefore, grow six times as fast as one in the forest under crowded conditions. Consequently there is likely to occur much misconception regarding the age of living trees on account of the marked variation in their rate of growth under different conditions. The white pine, according to historical tradition, developed 6 feet in diameter and 250 feet in height in the New England primeval forest, and elms as street trees are known to have lived two hundred years. There are instances in Massachusetts where elms have lived to be three hundred years old. Many shade trees live to be one hundred and fifty years old and even more, and this age is not uncommon for forest

trees. Trees, however, do not grow with the same uniformity throughout their period of existence. At first they start in to grow more or less slowly, which is generally followed between the tenth and thirtieth year by the

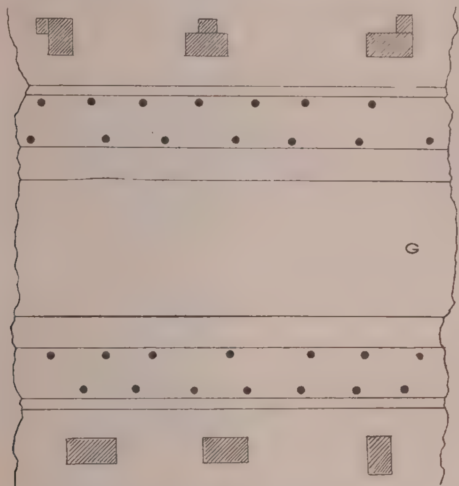

FIG. 11. — Plan of street at Hadley, Mass., approximately 300 feet wide, provided with two driveways with green (G) in center and generous tree belts.

maximum development, this being followed throughout the remaining cycle by a gradual diminution in growth. (See Fig. 10.)

The following list, showing the average growth of trees, represents approximately what a 3-inch sapling will develop into in twenty years.

	Inches.		Inches.
White maple,	21	Yellow locust,	14
American elm,	19	Hard maple,	13
Sycamore,	18	Horse-chestnut,	13
Tulip tree,	18	Honey locust,	13
Basswood,	17	Red oak,	13
Catalpa (*speciosa*),	16	Pin oak,	13
Red maple,	16	Scarlet oak,	13
Ailanthus,	16	White ash,	12
Cucumber tree,	15	White oak,	11
Chestnut,	14	Hackberry,	10

Streets and Avenues.

The modern city streets are, as a rule, much better laid out for tree planting than the older ones, although there are some exceptions to this. In the Connecticut valley, where there is considerable level land, the early settlers showed remarkable judgment and taste in laying out their

towns. Many of these old towns are arranged with exceptionally wide streets that from early times were systematically planted with shade trees. Some of these streets are 300 feet wide and have two rows of shade trees on either side of the street. On the other hand, many towns are poorly laid out, with no proper provision, or at any rate very poor provision, for planting trees.

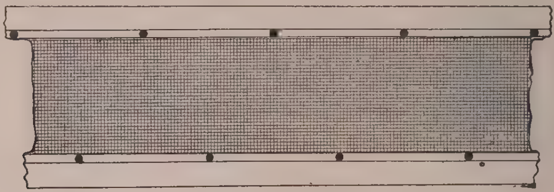

FIG. 12. — Narrow avenue, showing trees planted alternately about 45 feet apart.

Most towns will not accept a highway under 40 feet wide, which is narrow enough for tree planting; in fact, it would be much better if towns would not accept avenues less than 50 or 60 feet in width. Some of our modern cities, when laying out avenues, now make provision for a tree

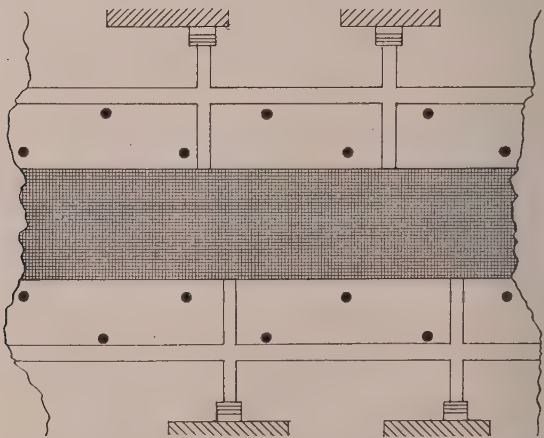

FIG. 13. — Plan of modern avenue provided with a 40-foot roadbed, 6-foot sidewalks, 23-foot tree belts, with alternating rows of trees 60 feet apart.

belt or a space between the curbing and the sidewalk where trees may be planted. This space should be at least 4 feet wide, and 20 or even 30 feet wide is better. A tree belt 2 or 3 feet wide is far better than none, since this allows some space for planting. In case the sidewalk comes next to the curbing, and a special tree belt is lacking, it is always advis-

able to plant the trees near the abutter's line to protect them from horses, etc.; besides, the conditions for development are better here. When trees are planted too close to the sidewalk and curbing the roots interfere with them, and if the tree belt is narrow the roots are continually injuring the walks. In no case is it advisable to plant trees in the ditch, or even so close to the roadbeds that they are likely to be constantly scarred. Wide tree belts make it possible to alternate two rows of trees and secure more massive effects. A street having wide tree belts provided with good soil furnishes an excellent opportunity for tree growth and development, and with the installation of the best modern gas lines, sewer conduits, etc., there is no reason why trees should not flourish under these conditions. When the streets are narrow it is desirable, if conditions will permit, to plant alternately. This system allows much better opportunity for development of the trees.

Besides the tree belt, many of our modern cities reserve a space in the center of the street for a miniature parkway, to furnish a chance for the planting of trees and shrubs.

Much more attention should be given at the present day to the laying out of streets, and towns should be more careful about accepting too narrow highways. The present generation might learn much concerning street planning from the early settlers of our New England towns.

Distance to plant.

Opinions naturally differ in regard to the distance apart to plant trees. In fact, we must expect to find a diversity of opinion in all matters relating to the care and treatment of trees and shrubs owing to the variable conditions under which they grow; neither are the results sought for always the same.

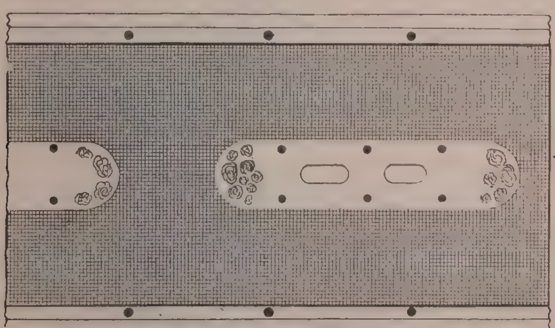

Fig. 14. — Plan of street with parkway and 6-foot tree belt.

If street trees are to be planted for their final individual effect they should be set far enough apart not to interfere with one another; but if

the effect of the avenue as a whole is aimed at they can be planted closer together. What holds true in regard to trees is also true of shrubbery. Some gardeners plant masses of shrubbery together to get the effect of the whole, while others plant for the individual effects. Trees planted 20 or 25 feet apart will interfere in a few years, and if allowed to remain at this distance the individual effect of the tree is destroyed, although such close planting on an avenue is often effective.

In one city which we recall the elms were planted 25 to 30 feet apart many years ago, presumably with the intention of future thinning, but as no one apparently ever had the courage to do this, the trees have now so developed as to interfere, and as a result have become deformed through crowding. It is now too late to practice thinning on these streets. While their individual characteristics are destroyed by their restricted development, yet it must be confessed that the high Gothic arch effect produced by such close planting is effective.

FIG. 15. — Street with tree belt, showing close planting.

When trees are planted very closely, every other one can eventually be taken out. The principal difficulty with this method is the courage required to do it; besides, in most places a hearing would have to be given for their removal which might meet with strong opposition. In one instance ash trees were planted in a row 25 feet apart. The limbs touched in twenty years, and later every other tree was removed, leaving the trees 50 feet apart. At their present rate of growth it will be some years before they interfere with one another.

The limbs of medium-sized rock maples planted 40 feet apart will interfere, as will those of larger trees of this species when planted 60 feet apart. A good average distance for planting most street trees, however, is 45 to 55 feet. Even 70 to 80 feet is not too far apart to plant elms in some localities, as this tree grows to a large size, with a wide spread of foliage, and we are familiar with specimens of rock maples growing along a roadside which have a spread of 75 feet. For smaller trees, such as the European linden, 30 feet apart is not bad. Many maples are set 50 feet apart, and in localities where the development is slow and they do not attain a large size, even 40 feet apart is suitable. When the growth

of permanently planted species is slow, alternating trees of quick growth, like the Italian and Carolina poplars, is advisable, and when the more permanent trees have reached a fair height the poplars may be removed.

Country Roadsides.

One of the wisest provisions of the Massachusetts laws relative to shade trees is that trees and shrubs bordering country roadsides shall be protected by statutes similar to those in residential districts. Much of the senseless slashing of roadside shrubbery so long in vogue is now largely prevented. New England country roadsides are unsurpassed in beauty, and the miscellaneous character of trees and shrubs to be found growing along them is a source of great pleasure to tourists.

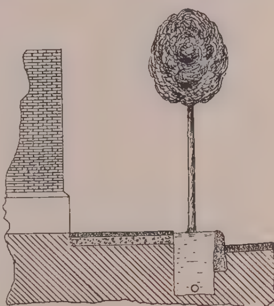

Fig. 16. — Illustrating method of growing trees on busy thoroughfares. The conventional type, such as the Oriental plane which tolerates severe annual pruning, is planted between the sidewalk and curbing in a rich loam 3 or 4 feet deep, provided with special subirrigation tile.

There are several ways of treating country roadsides. One of these methods is to maintain a regularly planted tree belt on a graded and neatly kept roadside, which results in a conventional effect. Another scheme consists in allowing the development of shrubbery and eliminating the tree growth which is often objectionable when crops are growing up to the highway. Or a system combining both shrubbery and trees may be employed, allowing the trees eventually to crowd out most of the shrubbery.

Most roadsides are lined with a miscellaneous growth of shrubbery and trees, located irregularly, which produce good effects, but when conventionality in the surroundings has been aimed at the well-kept roadside and tree belt are legitimate. However, there are roadsides on which no trees or shrubbery can be allowed, — for instance when the road runs through valuable farm land used for more or less intensive agricultural purposes. Trees absorb a great deal of moisture, and this factor and the shade produced interfere greatly with crop production.

For generations roadsides have been used for dumping grounds by certain misguided persons, and one of the objects of maintaining roadside shrubbery in its natural condition is to cover this extreme unsightliness from view. Unfortunately many think they are conferring a benefit on the public when they cut roadside shrubbery and leave it beside the road to decay. Roadside planting is Nature's planting, and is envied by the best landscape architects. It has the merit of intrinsic beauty; it is harmonious, no matter how heterogeneous the mass may be, and never becomes tiresome or monotonous like conventional planting. Many

of the shrubs and vines which decorate roadsides are now used extensively by landscape gardeners in planting, and various species are very highly prized.

The native shrubbery consists of the various elderberries, Viburnums, honeysuckles, cornels or dogwoods, hawthorns, hollies, sumachs, azaleas, laurels, blueberries, etc. There are also such species as the chokecherries, witch-hazel, sassafras, alders, etc.

FIG. 17. — Country roadside, showing spontaneous growth of native species.

The most characteristic New England country roadside trees are the chestnut, various oaks and maples, hickories, ashes, pines, hemlock, elm, cherries, hornbeam, tupelo, birches and poplars. They are found growing in all sorts of combinations, mingled with different types of shrubbery, vines and herbaceous plants, with resulting effects quite unlike those obtained by artificial planting. Aside from the removal of briers and other growths too close to the roadbed, or the cutting out of the natural vegetation near abrupt curves where its presence constitutes an element of danger to traffic, or in cases where some legitimate scheme involving permanent improvement is concerned, roadside shrubbery should not be destroyed. There are, of course, occasions when the cutting of roadside shrubbery is desirable to improve the new growth which soon follows, but this should be done with discretion and care.

Root Characteristics.

There are well-defined differences in the development of the root systems of shade trees. All seedlings develop what are termed primary and secondary root systems; the former are known as taproots and the latter as laterals. In certain species like the red cedar the taproot develops quite extensively. In young trees its function is relatively more important than in older ones; hence it is usually easier to transplant large pasture cedars than small ones, which are more dependent on the taproot.

The lateral root system in some trees is well developed, and those having this system are in general the easiest to handle. The elm, maple,

hemlock, pine and others are easily transplanted with little loss because it is not difficult to obtain enough of the lateral root system to supply the tree. Some species, however, possessing lateral root systems appear to be dependent upon root fungi (*micorhiza*), which restricts them to particular soils and renders them sometimes difficult to get established in certain localities. Many plants, like the sumach and others, possess long, creeping lateral roots which must be taken up carefully to insure successful transplanting.

Depth of Roots.

Some idea of the depth to which roots extend may be had by examining excavations near trees, and also to some extent by plowing. Most elm and maple roots are confined within 2 feet of the surface, but in wet soil they are generally much nearer than this. The large roots of the European larch are very near the surface, and usually somewhat exposed. Pine and hemlock roots are frequently seen running on top of the ground, and in swamps, where trees often blow over, it may be observed that the entire root system is located within a few inches of the surface. Oak and chestnut roots do not appear to penetrate very far, as shown by the ease with which winds uproot the trees when growing even in ordinary soil. The maximum number of roots of most trees in ordinary soil is probably located between 1 foot and 18 inches below the surface.

Roots often penetrate soil to great depths, and when growing in gravel become flattened out in irregular shapes from growing around large pebbles. Apple tree roots have been known to grow through a mass of coarse gravel 8 feet to obtain water, and elm and rock maple roots will penetrate quite a distance to reach a water table. The roots of the common clover one year old have been known to descend to a depth of 8 feet; those of parsnip more than $13\frac{1}{2}$ feet; and of lucerne, a leguminous plant, more than 20 feet. The roots of a leguminous tree growing in India have been traced to 69 feet below the surface without reaching their full length.

The distance to which roots extend laterally may generally be roughly determined by the spread of the crown. Practically all trees extend their roots beyond their foliage or branches. The Norway spruce and others, which have narrow crowns, do not have an extended lateral system. The maple and elm have well-developed root systems which extend to a considerable distance.

There is a correlation between the shape of the aerial portion of a plant and its root system. The leaves of root crops like radish, turnip and others are so placed on the stalk that they divert the rain toward the axis of the plant, or taproot. On the other hand, the apices of the leaves of many plants are deflected away from the axis, *i.e.*, toward the lateral or feeding roots. Most shade trees are noted for their large crowns, with the leaves pointing away from the trunk and directing the rain where it is most needed, whereas the soil near the trunk does not receive much water. This feature admirably illustrates biological adaptation.

Such trees as the balm of Gilead and Italian poplar possess extensive root systems. This is evident from the root suckers which may frequently be seen coming up quite a little distance beyond the spread of the branches, and many roots will grow in a horizontal direction to great distances. There is an authentic case of an elm whose roots were found in abundance 75 feet from the trunk, — just the height of the tree. In another case the roots of an elm were found obstructing drain tile which was 450 feet from the tree. The leading roots of a pear tree developed in 60 feet of a line of drain tile during five years measured 8,498 feet (1.61 miles); if smaller roots be included, the total length was about 2 miles. A squash grown in a greenhouse produced in a few weeks a total of 15 miles of root growth, or over 1,000 feet of roots per day.

Obstruction of Sewer Tile, etc., by the Roots of Trees.

The obstruction of sewer services and drain tile by tree roots has in some places become such a nuisance that steps have been taken in certain cities to obviate it. The elm is a troublesome tree in this respect, often completely filling land drain tile for long distances with roots, and putting the tile out of commission.

The Carolina poplar is a more troublesome tree, however. This causes so much damage to house sewer connections that its use for planting has been discontinued in some sections. The Carolina poplar is a tree of such rapid growth that an extensive root system is developed in a short time. Sewage appears to have an especial attraction for the roots of this tree. They seem to have no difficulty in penetrating even the cement joints of Akron tile, and when once in the tile the root development is remarkable. In one city as many as eighteen sewer services had to be taken up and repaired in one month the sections were so badly congested with roots of the Carolina poplar. Other tree roots occasionally enter tiles, cesspools and wells, but the Carolina poplar appears to be the greatest offender in this respect.

From the results of numerous experiments covering a period of years it is evident that roots can be kept from penetrating drain tile by properly packing the joints with chemically treated fibers, which destroy the delicate roots as they attempt to enter.[1]

Branching Characteristics.

There is considerable difference in the branching habits of trees. This must be understood before a tree can be developed along desirable lines. The red and Norway maples have a habit of sending out large branches or secondary leaders at more or less oblique angles, very close to the ground. If allowed to develop, these render the trees undesirable for street use; but if started right when young by pruning, such trees may be trained to meet the requirements of residential streets. However,

[1] Mass. Agr. Expt. Sta. Rpt. 23, Pt. 2, p. 35 (1911).

if pruning is attempted when they are fairly well developed, great injury results, and the symmetry of the tree may never be entirely regained.

The habit of the rock maple is to produce one or two strong vertical leaders, and its ultimate development is such that it seldom gives much trouble so far as pruning is concerned.

The branches of the pin oak are low and drooping. This objectionable feature detracts from the value of this tree for use on streets, but may be overcome by high pruning.

The branching habits of the elm, on the other hand, make it one of our most desirable shade trees, the branches invariably forming acute angles with one another. Elms oftentimes develop low, more or less horizontal branches, but these possess no permanent value and may subsequently be removed. The ideal mature elm offers no obstacles to street traffic, and even the wires of public service corporations seldom interfere with the branches.

On the other hand, evergreens, like the Norway spruce, branch to the ground, and for their best development they should never be placed where it is necessary to prune them, as cutting the lower limbs of the Norway spruce and most other conifers detracts greatly from the beauty of the trees.

Many trees, including some of the maples, birch, oak, chestnut and elm, and most shrubs, have a habit of suckering or sprouting from the roots. Much of the timber growth such as the chestnut is of this nature, and is termed "sprout growth." This growth is very common in woodlands and along roadsides which have been cut off. Trees originating from root suckers do not possess the value of those grown from seed, and consequently should not be used for transplanting. Stump growth may develop faster for the first few years than seedlings, but later growth is often slow. As the sprout growth reaches maturity it generally becomes involved with the stump, which ultimately decays, leaving an ugly cavity at the base of the tree. Most sprout growth shows abnormalities in the foliage the first few years, and it is likewise more susceptible to aphis. The extensive root system of the tree which nourishes it induces malnutrition or overfeeding characteristics which are pathological.

The formation of sprouts on the trunks and branches of trees is of great value in their restoration. Sprouts sometimes originate from the callus of wounds, and are quite serviceable in accelerating healing.

Soil Conditions, Texture, etc.

It requires only a glance at the trees of any particular region to observe their natural choice of environment. While this does not always mean that trees will not grow elsewhere with the same degree of vigor as in their natural habitat, — indeed the growth is often more vigorous, — they are very likely to prove less resistant to various troubles. One cannot be always certain, however, that, because a species is restricted

to a particular location or habitat, it has realized its optimum condition for development. In some cases there is reason to believe that their choice may be determined by some minor inherent peculiarity common to the species, such as seed habit.

Some species of plants are confined to dry soils, while in other locations the same species grow in moist situations. In a botanical sense these are identical species, but they may possess such different physiological adaptations as to warrant the term "physiological species."

Soil texture plays an important rôle in the distribution and development of plants, and is inseparably associated with water-retaining capacity. Soil texture affects the color, size and thickness of the foliage, and also has an influence upon susceptibility and nonsusceptibility to certain troubles.

Even in limited areas trees possess different habits of growth, and soil texture is probably the most important contributory factor. For example, the elms in the eastern part of Massachusetts are different from those in the Connecticut valley. Those growing in the Housatonic valley differ from either, assuming a more vase-like form and being characterized by the development of a larger number of vertical leaders or branches. The greatest number of symmetrical elms and the best types of branching occur in this region.

The rock maples in the Connecticut valley are of a different type from those found elsewhere, growing larger and more luxuriantly. This region is characterized, also, by the occasional occurrence of a beautiful, dark-colored, densely foliaged form resembling the black maple, *Acer saccharum* var. *nigrum*, noticed farther west. Like the elm, much difference in the branching habits of the rock maple may be observed here and there which appears to be characteristic of certain localities.

There is, however, a wide diversity of conditions in nature under which trees may live and develop. The rock maple, oak and hickory appear to be at home on our rocky hillsides, while the basswood, canoe birch and beech are adapted to soil containing humus. The chestnut is confined largely to clay hills or "drumlins," where it has grown since time immemorial. The sycamore, pin oak, red maple, tupelo and swamp white oak are confined to low, moist soil; while the scarlet, red, white and yellow oaks, pitch pine, poplar, gray birch and red cedar prefer drier locations. The willows, Carolina poplar, red birch and hackberry are closely restricted to streams; and the white cedar, tamarack and black spruce to swamps. The white pine is quite generally distributed, and in New England it is adapted to a greater variety of conditions than any other tree in our flora.

Notwithstanding the wide diversity of conditions to which our native trees are subject, they can with care be made to thrive under different conditions. Rhododendrons may be grown successfully in dry soil having 2 or 3 feet of muck placed underneath, and trees adapted to moist places will develop well in poor soil if freely supplied with fine-textured loam.

The moisture content of a relatively dry soil may be greatly modified by the addition of organic matter, which increases the water-retaining capacity and makes the soil more suitable to swamp-loving species. But swamp trees that make excellent growth in dry soil need to be supplied with water during drought periods.

There are other factors than those of soil texture, water supply, etc., that influence the distribution of plants. The chemical composition of the soil affects the habitat of trees, and is capable of modifying to some extent their mode of growth. Many plants are restricted in their range owing to differences in the chemical composition of the soil. Certain species are practically confined to the seacoast, where the percentage of chlorine in the soil is greater than it is inland; but these species may be grown successfully elsewhere. The amount of humus in the soil affects the growth of trees materially. While 20 or 30 per cent. of organic matter was formerly contained in the upper strata of our soils, now not more than 2 to 5 per cent. may be found in a large portion of it. Organic matter has a vital effect not only on the physical properties of soils, but on their chemical and biological properties, influencing the development of *micorhiza* (beneficial root fungi) that are intimately associated with the roots of some of our shade trees. Soils also contain toxic elements that are often found in sufficient abundance to make it difficult to establish certain species in the desired location.

It is desirable in all cases when planting trees to give them conditions closely approximating their requirements as determined by their natural habitat. Elm trees often grow in swamps, as well as in dry and sandy soils, but both of these habitats produce poor specimens. The swamp tree is usually of inferior shape, and sandy soil as a rule produces a lank, spindling growth, with inferior foliage. Even the best type of elm, if planted under uncongenial conditions, will make poor development regardless of its inherent qualifications. The elm, therefore, should never be planted in dry, gravelly soil without being supplied with a large amount of good loam of the proper texture. The rock maple, on the other hand, will endure a dry soil much better than the elm, although if too dry borers may affect the tree. The scarlet and black oaks will thrive in such a soil.

In general, the texture of the soil in most towns is fairly well suited to the growth of a large variety of trees. The soils often lack organic matter, hence the application of loam is advantageous. On the other hand, some of our New England river valleys are particularly adapted to the growth of elms and maples, and the addition of loam in such cases is not so necessary.

Street trees are too often forced to exist under extremely unfavorable conditions; therefore they require different consideration from those more favorably located. Many city trees are planted in made soil, and some of the refuse found in these fillings is hardly adapted to tree growth. Such soils are, moreover, likely to be deficient in organic matter and plant food, and are often in such poor mechanical condition that the soil capillarity is of little account.

Soil Covers, Lawns, Macadam, etc.

The nature of the soil cover surrounding trees is scarcely less important than that of the soil in which the roots are growing. We find trees growing under many different conditions: *e.g.*, lawns, mowings, cultivated fields, paved and macadamized roads, sidewalks, etc., and it is hardly necessary to point out that cultivation is much superior to all other conditions. The importance of tillage is scarcely appreciated in the case of ordinary crops, even by lifelong farmers. Stirring the soil, even without the use of fertilizers, has enormous influence on the growth of crops, and is also an important factor in the control of various tree pests, a thrifty tree being more resistant to infection. Cultivation not only aerates the soil, but breaks up the capillarity and conserves the moisture, — of great importance in dry soils.

Examples of the good effects of cultivation on shade trees may be seen in the many specimens growing luxuriantly in soil in which crops have been cultivated for years. Trees under these conditions branch freely and produce large leaves of a deep green color. Cultivation of the soil about trees for even one year has a decided effect.

Next to cultivation, lawn conditions are perhaps the best. The grass, which is constantly being mowed and left on the ground, acts as a mulch and conserves the moisture. Some of our best trees grow in pastures, where the conditions are often unfavorable to the growth of grass or where the grass is kept closely cropped by grazing. A mowing or hay field is one of the worst possible locations for a tree, the elm being particularly susceptible to the ill effects of such an environment. Measurements of elms growing on either side of a road, one series being under partial lawn and the other under partial mowing conditions, showed differences in their development. The average growth of these trees during a period of twenty-five years is as follows: those on the lawn side of the road had a circumference of 56 inches, while those on the other, or mowing, side were only 49 inches. In another case the average circumference of lawn trees was 37 inches, and that of the mowing trees, 26 inches. These trees, which had been growing under these conditions for many years, were of the same age, and were so located that the difference in light intensity cannot be considered a factor in their development.

The extensive use of various materials for paving roads can hardly have a beneficial influence on tree growth. In some cities a great many trees are found on streets paved with asphalt from one block front to another, allowing nothing but a small space around the trees unpaved. It is a question in such cases where the trees obtain their moisture, although they exist year after year, and make some growth. No doubt some water is obtained from catch basins and sewers; at any rate, moisture is usually found in the soil under the most impervious substance employed in paving, and during the most severe droughts trees on paved streets often suffer less from lack of water than others apparently more favorably

located. This may possibly be explained by the fact that whatever moisture reaches the soil under these paved streets is to a certain extent conserved, the surface evaporation being less than where no pavements are found. The severity of the conditions to which trees are subjected when surrounded by pavements varies considerably, and when more or less water is allowed to leach through them the soil moisture conditions cannot be unfavorable. The more thoroughly a roadbed is sealed the more soil aeration must be affected. How largely this factor enters into the problem is unknown, but while trees do survive under extremely severe conditions, their length of life must be limited.

Excavations, Curbings and Sidewalks.

Remodeling and regrading streets are a frequent cause of injury to trees. In placing curbstones large roots are often cut, and in regrading streets so much soil is frequently removed that the base of the tree is left high in the air and the exposed root surfaces become injured by traffic. Besides these mechanical injuries, the exposed roots are likely to be injured from other causes such as winterkilling, sun scald, road oil, etc. If the roots are cut to any extent the tree deteriorates in value, and if grown under other unfavorable conditions it usually succumbs to a lingering death. Again, root mutilation too often takes place when sidewalks are being laid, and it is quite difficult to prevent it when the trees are large and have extensive root systems. The cement sidewalk with its deep foundation constitutes more of a menace to roots than a tar or brick walk, but if care is used in excavating, much root cutting may be prevented. The roots of trees located under a modern roadbed have little chance of remaining uninjured, with the sewers, water pipes, gas lines, telephone systems, electric wire and other conduits that are constantly being installed. Electric railways may also cause injury to trees in various ways. It is more injurious, of course, to the tree to cut the large roots close to the trunk than the small ones some distance from it. In widening a certain road a few years ago 4 or 5 feet of the banking adjoining a row of ash trees were removed, destroying a large number of the smaller roots on the west side of the trees, but this cutting had little or no noticeable effect upon the trees. They were young and vigorous, and on the east side the roots extended into cultivated ground, apparently soon making up for the loss on the roadside. Since the cutting of these roots, every other tree has been removed, and measurements of the rings of the stumps show that not the slightest retardation in growth had taken place following the operation. One fact should be remembered: mutilation of the root system is not so serious as that of the stems and branches, the former responding more quickly to the stimulus caused by mutilation. In transplanting young trees 80 to 95 per cent. of the essential part of the root system is usually destroyed, and even with a slight pruning of the top the tree usually survives when the work is properly done. Indeed, the cutting of the roots has been known to be beneficial, as, for instance,

in the case of gas leaks in the street. Many cases are known to the writer where large trees have escaped gas poisoning owing to the fact that when the curbing was put in some of the larger roots leading towards the gas main were destroyed; therefore when leakage occurred there were no roots favorably located to absorb the poisonous substances.

The cutting of roots on vigorous trees is not so serious as cutting those of old trees. In the latter case judgment should be exercised as to root cutting.

Effects of Light and Shade.

Most plants are quite susceptible to light and shade. Those which require light are termed photophilic (light friendly), and those which thrive best in shade, photophobic (light shunning). Shade has an unfavorable effect on plants, causing a spindling growth and rendering them more susceptible to diseases. On the other hand, too much light is detrimental to certain species. The dense shade from street trees interferes at times with the growth of grass and shrubbery on lawns. Since there are relatively few varieties that are adapted to shade, it often becomes a problem as to what to plant in such locations. However, a glance at any native flora will give a hint of what is best adapted to shady places. Such wild species as clethera, rhododendron, hobblebush, leatherwood, moose and mountain maples, laurel and honeysuckle tolerate shade, and there are some exotic shrubs, such as *Ligustrum regelianum*, *Symphoricarpus vulgaris*, *Xanthorrhiza apiifolia*, etc., and vines like *Euonymus radicans* and *Vinca minor*, that are adapted to shade.

Notwithstanding the fact that shade is natural to some species, they develop a less spindling growth in light. Shade trees require light; hence for their best development they should be planted far enough apart to prevent interference and spindling growth. The effect of shade on trees when growing thickly together is a dying of the lower branches, inducing growth in height at the expense of spread of the crown and growth in diameter.

The variation in light intensity differs, as is well known, during the year. Light intensity is also variable in different localities, and there are definite variations that occur in light intensity during the day which are more pronounced at some seasons of the year than at others. The difference in the amount of sunshine peculiar to any region is not dependent on latitude but on other conditions. For example, the number of hours of total sunshine occurring during the year at Boston, Mass., is 2,493; Cleveland, Ohio, 2,075; Chicago, Ill., 2,616; Milwaukee, Wis., 1,865; Seattle, Wash., 1,973; Elkins, W. Va., 1,737; Phoenix, Ariz., 3,742, and New Orleans, La., 2,378. These marked variations in the number of hours of sunshine show that latitude does not necessarily constitute an important factor in determining light conditions. The amount of possible sunshine, according to the United States meterological observatories, varies from 37 to 84 per cent. Variations in light intensity

or number of hours of sunshine are correlated with growth and development of vegetation, although temperature is very important too.

Morning light is more intense that that of the afternoon, and this difference exerts an influence upon the growth of trees. Measurements of a large number of tree stumps ranging from ninety-five to two hundred and twenty years old showed 17 per cent. more growth of the radii on the east side than on the west, and the radii measurements attained from the stumps of a row of ash trees running north and south were 24 per cent. greater on the east than west side. Two rows of trees bordering either side of a road running approximately east and west showed a difference of 11 per cent. in their circumference growth 4 feet from the ground, during a period of seven or eight years, in favor of the south row. Daily measurements of light made by us for one year showed an average difference of 10 per cent. in favor of morning conditions. Since photosynthesis or carbon assimilation is proportionate to light intensity, and growth is in proportion to photosynthesis, there naturally follows a greater growth on the east than on the west sides of trees, and the same holds true for the east and west slopes of high elevation. The light conditions at high elevations are more intense than low elevations, and the difference may equal 25 per cent. more or less, depending upon the altitude and other conditions.

Light is an important factor in the process of photosynthesis or carbon assimilation in leaves, about 95 per cent. of the structural material of the tree being obtained by this process. Light inhibits growth and stimulates the formation of mechanical and resistant tissue; on the other hand, darkness or lack of light stimulates growth. Light affects the size, color and texture of the foliage, and, in fact, the whole configuration of the organism.

Since morning light conditions are better than those in the afternoon it is well to set trees with their poorest developed sides towards the southeast, as they will become more favorably exposed to light conditions; hence they will develop more rapidly on this side. Moreover, an avenue of trees located on the east and south sides of a road will develop more rapidly than those on the west and north sides, and trees and crops located on the east side of a hill will develop more rapidly than those located on the west side. An east exposure is therefore much better for the rapid development of an orchard than a west exposure, and the same holds true for different crops and shade trees.

Transplanting.

Too little attention is given to the details of transplanting. It is quite essential that soil conditions should be suitable for the growth of the particular species of tree planted, and in the selection of material for planting there is great need of more care. A large amount of poor material is constantly being used, besides which, injudicious use of the knife and pruning shears maims many trees for life. Trees 6 to 8 feet high are usually

too small for street planting, not being so well adapted to street conditions as larger ones ranging from 1½ to 3 or 4 inches in diameter. Moreover, by using larger trees one can obtain a better idea of their future development and configuration.

The life cycles of trees are by no means identical even in the same species. The conditions which a certain species seems to require at one period of its existence are less suitable for another period, especially as regards soil requirements for root development, older trees appearing to tolerate certain conditions better than younger ones. Young trees 5 to 6 feet high will often fail to grow for some years after transplanting under the poor conditions often prevailing on streets, while larger ones will start immediately to grow.

Much more attention should be given to the type of tree transplanted than is generally given. The same species varies greatly in different localities. Lopsided elms should be avoided, and only those selected which possess a habit of growth calculated to produce a desirable type. It is worth while to secure elms from those localities where the most perfect types abound.

FIG. 18. — A State highway specimen of elm worthless for future development.

In localities where much desirable native material exists this can be used to advantage for street planting, and if carefully handled it will prove successful. Native material, or that gathered from the fields, however, is much improved by nursery conditions, and two or three years under such conditions are desirable when utilizing native stock.

Most competent authorities recommend planting a few trees well rather than many poorly, and when one recalls the large amount of poor planting seen around dwellings, and the weak-looking specimens of trees and shrubs, this advice will appear pertinent.

Town funds[1] do not always allow the appropriation of a large sum of money for transplanting trees, and one must do the best he can with the conditions under which he has to labor. Special attention, therefore, should be given to the adaptability of certain species to the conditions at hand, since the cost of extensive preparation and soil modification is too often beyond the funds allowed for this purpose. The advice given by Olmsted Brothers, landscape architects, in one of their reports, regarding the planting of elms, is to the point: —

[1] During the year 1914, 12,498 trees were planted by tree wardens in 58 cities and towns in Massachusetts.

It would be better to prepare tree beds 2 to 3 feet deep and 20 to 30 feet square, filled with good loamy soil where the present ground is dry and sandy gravel, even if the expense of doing so would be so great that only one tree a year could be planted.

Few trees, however, outside of those planted in the Arnold Arboretum and on a few private estates receive any such treatment. It must be borne in mind in planting that shade trees are always under more or less disadvantageous conditions as regards atmosphere and soil. Hence it is of the greatest importance that they should be aided as much as possible, and the time is not far distant when much more specific methods must be employed in the planting of street trees in thickly settled communities. Even at the present time, where ideal conditions are sought much more money is spent in preparation for transplanting than in purchase of the trees. The majority of street trees which are planted are not supplied with loam or placed in holes over 2 or 3 feet wide and 15 inches deep, and some of them are given space only large enough to contain their roots. Loosening up the soil to a considerable depth is very important, as shown by the results of the use of dynamite in the preparation of soil for transplanting. A hole 5 to 6 feet wide by 20 inches deep in any case should be the smallest used, and it should be as much larger as can be afforded.

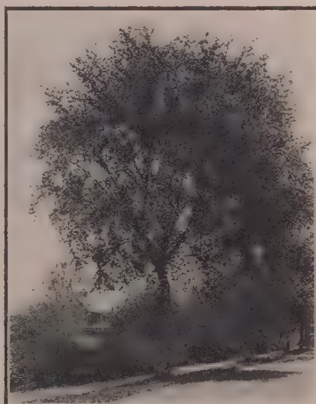

FIG. 19. — Elm severely cut back when transplanted. This has destroyed its natural symmetry.

When digging up young trees the roots should be preserved as much as possible, and the more earth taken up with the roots the better. The roots should not be exposed to sun and wind, and if possible should be kept covered and moist. For this purpose damp straw, bagging or sphagnum moss may be used.

It is usually the practice to place the best side of the tree toward the north and the poorest toward the south, since the light conditions on the south side are better, and naturally better growth results. It is also advisable to lean a tree toward the direction of the prevailing winds, and if these are strong enough to interfere with the growth of the tree it should be fastened to a strong stake. Trees obtained from the field where they have been growing close together have long, slender shafts and are top-heavy. When such trees are planted in windy situations it is necessary to support them by stakes.

When the ground is prepared for planting, the injured roots should be recut so that healing may take place, and before being covered they

should be properly arranged in the soil. According to good authorities trees should never be planted more than two or three inches deeper than they originally grew, and too deep planting often causes their death. It is more convenient for two men to set out a tree than one, as one can hold the tree in the proper position while the other is filling the soil in around the roots.

The top soil, if of good quality, may be used, but it is better to discard the poorer subsoil and replace it with loam. Much depends, however, upon the nature of the subsoil and whether the species is adapted to grow in it. In any planting the best soil should be placed at the bottom of the hole or under the roots, and the sod when properly pulverized may be used, care being taken not to interfere too much with the soil capillarity. The poorer soil which covers the roots may be enriched and its texture improved by working in manure or other organic matter. Manure, however, should be sparingly used and thoroughly incorporated with the loam, care being taken not to bring it in too close contact with the roots. Towns and cities which do much transplanting might make good use of composted street cleanings; and if land were available for a small nursery, it could be used to good advantage by tree wardens and foresters.

When a tree is being set out the soil about the roots should be well tamped. Many people apply water to the roots at the time of transplanting, and if the season is an unusually dry one the watering may be repeated occasionally. But persistent watering is injurious, and young trees are sometimes killed in this way. If the soil around the roots is well tamped when the trees are set out it is not essential that water should be applied at all, and it may even be injurious by washing the soil from the roots and leaving air spaces. One of the most essential features in transplanting is to secure as nearly as possible normal conditions of the soil about the roots. It may be mentioned here that watering large trees near their trunks is not a wise practice, since the feeding roots are quite a distance from the tree. One would suppose that an elementary knowledge of tree growth would discourage such a course, although it is possible, by constant watering and cultivation, to encourage the formation of roots at the base of the tree.

After the tree is set out a mulching of hay, straw or horse manure containing considerable straw may be used to help conserve the moisture in the soil and to keep down the grass and weeds which rob the soil of its moisture and food.

Transplanted trees require a certain amount of pruning to accommodate the leaf and root systems to each other, and it is usually necessary to cut back the branches to meet these requirements. (See Pruning.)

There are differences of opinion in regard to methods of transplanting trees, and undoubtedly more than one method may be used. Opinions also differ in regard to the best time of year for transplanting, but it may be said that most persons prefer the spring to the fall. We are of the opinion that it is not advisable to plant too small trees, preferring elms

and maples $2\frac{1}{2}$ to 4 or 6 inches in diameter, since they take hold of the soil better.

At the present day many very large trees and shrubs are being transplanted successfully. Special machines have been designed for use in this work. The Hicks Tree Mover, designed by Mr. Isaac Hicks of Westbury Station, Nassau County, N. Y., is extensively used, and Mr. Hicks has achieved remarkable results in handling very large specimens of trees and shrubs. These tree movers are expensive, however, and for trees 6 to 10 inches in diameter a pair of high, heavy truck wheels, with some simple improvised arrangement, may be adapted. At the present time many individuals are willing to pay a good price for large trees, for which tree movers are admirably adapted and should be more extensively used.

A general tendency has been to plant street trees rather closely, with the idea in some cases of cutting every other one when it should become necessary. The courage to do this when the time comes is often unfortunately lacking, however, and the trees are allowed to grow and crowd one another until it becomes too late to thin them out.

The loss from transplanting need not be great, although there is a great deal of difference regarding species in this respect. During a normal season the loss from transplanting need not exceed 2 or 3 per cent., and sometimes 100 trees from 100 will live. During severe drought periods a greater loss is expected, and even 50 per cent. loss in a good season occasionally occurs from poor planting. Such trees as the tulip tree and tupelo are naturally difficult to transplant with success, and a considerable loss with such species is anticipated.

Tree Surgery.

The term "tree surgery" is a legitimate one to use in describing modern methods of treating trees, as they are similar to those used in human and animal surgery, *i.e.*, the treatment of trees is based upon aseptic and antiseptic methods.[1] In the same manner that modern surgery is successful in correcting deformities, performing operations, etc., so a young and vigorous, although often imperfect, tree may be improved and rendered more valuable by the use of the same methods. While old and decrepit trees are often treated to extend their period of usefulness, it should be borne in mind that it is more desirable to care for the younger, more promising trees, and it is only too apparent that if more attention had been given to the care of old trees at the proper time they would never be in the condition in which we often find them.

Unlike the surgeon, who has no choice of subjects, the tree expert can select his individuals at the start and eliminate the imperfect specimens,

[1] Some prefer the term "tree repair work" to that of "tree surgery" on the ground that the work is of a much cruder type than that generally recognized as "surgery." There are, however, many instances where as much skill and knowledge are required in this work as in animal surgery.

although in the process of development trees need constant attention. It is desirable that antiseptic methods of treatment following pruning, mechanical injuries, etc., shall be adopted.

Pruning.

Besides the necessary pruning at the time of transplanting, the removal of dangerous dead wood and branches every two or three years is essential. In the case of street trees the lower branches frequently need removing or lightening up. When limbs are so close as to interfere, thinning out is necessary to prevent their injuring one another; but this thinning may be overdone so as to affect the beauty of the tree. Some make a practice of thinning and shaping trees when young, thus preventing too much thinning when the tree reaches maturity. The amount of dead wood annually produced in trees is quite large, and it costs about as much to dispose of it as it does to prune it away.

FIG. 20. — Specimen showing poor pruning. Note the long stubs.

In towns a distance of 10 or 12 feet or more may be left between the roadway and the lowest limbs, but in cities the nature and amount of traffic necessitate higher pruning. When street trees are growing close together high pruning is often necessary in order to let in sufficient sunlight, and when different types of trees are planted together, such as maples and elms, the pruning is often high in order that the high canopy or Gothic arch effect formed by the elm trees may not be destroyed. If a more or less symmetrical type in individual specimens is desired, the removal of certain limbs often changes the contour of the trees. We do not believe it desirable to prune the feathery growths often found on the trunks of elms, as they are apparently protective in nature; moreover, in our opinion they add to the beauty of the tree, taking away much of its conventional appearance.

As a rule, the limbs of vigorous maple trees will droop a foot or more a year owing to their increased weight, and in a short time they become too low. Limbs over a sidewalk may be left lower than over roadways. During rain and sleet storms limbs are heavily weighted and often give trouble when too near the ground.

On country roadsides pruning should be high enough so that the limbs will not interfere with hay and wood traffic. All limbs should be cut as close as possible to the tree, and cuts over 1½ to 2 inches in diameter

should be treated antiseptically to prevent decay. Strictly horizontal cuts should never be left. They retain water so that rot is likely to result, and

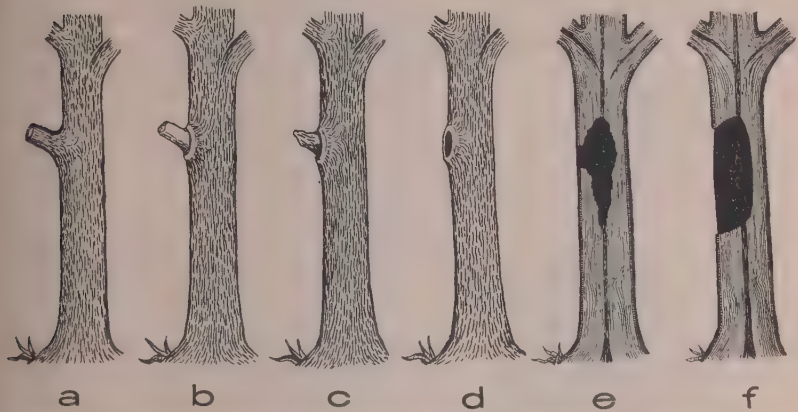

FIG. 21. — Showing the evolution of a cavity and method of treating it: (*a*) long stub left from pruning; (*b*) beginning of decay; (*c*) more advanced stage; (*d*) cavity formed in the wood; (*e*) longitudinal section of the trunk showing cavity; (*f*) cavity cleaned out and ready for orifice covering.

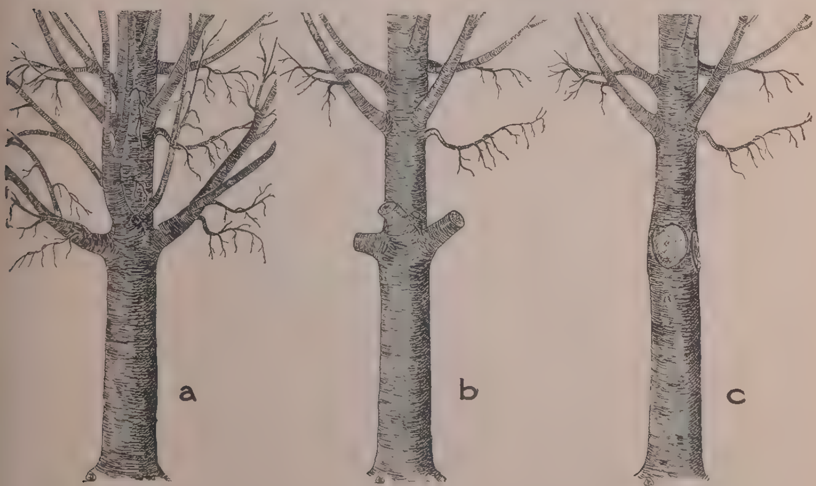

FIG. 22. — Method of pruning large limbs: (*a*) tree before pruning; (*b*) showing relative distance of first cut from the tree trunk; (*c*) the same with limbs cut close and the scars finished with mallet and chisel.

the cleaner the cut the better it will heal. There is, moreover, less chance for subsequent rotting.

Many of the cavities in trees are caused by leaving long stubs on the trunk of the tree, which become infected and disintegrated, the decay following back into the heart of the tree. (See Fig. 21.) It is therefore essential that close pruning and antiseptic treatment of the wounds should be practiced in order to prevent this decay. The plastic materials in a tree will not follow up a long stump and form a callus unless there are some branches left upon it which bear leaves, and even then healing is most likely to take place only close to the living branch of the stump.

Two or more cuts should be made when pruning practically all limbs to prevent peeling, and on limbs of any size it is necessary to make the incision on the under side for the same reason. (See Fig. 22.) After removing the limbs with a saw, a mallet and chisel may be used to smooth up the cut surface. This induces a better callus growth. It is well to prune carefully at the time of transplanting, when all street trees should be trimmed to a height of 8 or 10 feet or more. It is usually necessary at this time to prune for the purpose of balancing the root and branch system, and when this is done some of the less desirable branches may be sacrificed, and those remaining may be cut back to some extent, if necessary. However, a great deal of unwise and careless pruning of nursery stock and young trees is done, and many specimens are ruined in this way. Tree pruning shears should not be used in a haphazard manner, and a distinct idea of the object in view should be borne in mind. Moreover, species differ greatly in their response to mutilation, and what may prove of little consequence to one may be quite injurious to another.

FIG. 23. — Formation of a cavity in tree caused by the removal of a large limb, and wound not properly cared for.

The practice of topping trees is injurious, and should never be resorted to except in special cases. All of the reserve material in the tree is stored in the roots, stem and branches, and in a transplanted tree this is sufficient to develop the foliage. It is necessary that a young transplanted tree should have a certain amount of foliage for growth and development, since the rapidity of growth is dependent upon leaf development.

The type of trees termed "bean poles," having the tops so cut away that there are no limbs left, is not suited, therefore, to transplanting. Trees like the willow will survive any amount of mutilation, but elms, maples and others must be handled more carefully to obtain the best results. Pruning has a marked effect on the conformation of trees. Pruning the branches or secondary organs directs the energies of growth to the trunk, whereas topping, or the destruction of the leader, has the

reverse effect. Continual pruning of the lower branches induces the tree to grow taller than it otherwise would, and in some locations is advantageous to the tree. Topping is destructive to the formation of typical crowns in such trees as the elm, hornbeam, etc., whereas in other trees, like the Carolina poplar, topping or pollarding has a tendency to thicken them up and make them more desirable shade trees. The configuration of the crowns of maple trees is modified to some extent by topping them when they are young. This modification is manifested by

FIG. 24. — Too common method of pruning limbs, resulting in the disfiguration of the tree: (*a*) tree before pruning; (*b*) limb cut too close, resulting in the peeling of the bark; (*c*) unsightly wound caused by this method of pruning.

the more vertical growth of the branches, thus producing a more narrow crown.

The cutting back of old trees is usually disappointing. It is often a question as to whether this is worth while, although if not too far gone, old trees may be restored to a more or less vigorous condition by judicious pruning, tillage and feeding. When elm branches a foot or more in diameter are topped, nothing but a bushy growth results. By removing all but a single sprout, thus diverting the plastic materials, much better growth may be obtained, and replacing of the sacrificed member may be more readily obtained.

There is a difference of opinion as to the best time to prune, some authorities advocating spring and others preferring the fall of the year. Many people prune when the tree is in foliage, — in May or later. There are advantages in pruning in either season. Since trees occasionally bleed when pruned in early summer, painting the wounds is not always successfully accomplished under these conditions; on the other hand, scars on vigorous trees are likely to heal somewhat during the summer if the pruning is done early.

The tools required in pruning are as follows: for general work, a good coarse-tooth, wide-set saw (5 teeth per inch); for larger limbs, a small 3 or 4 foot hand cross-cut saw; and for smaller limbs not easily accessible, a pole saw is convenient. Pole-saw blades may be ordered through hardware dealers, and may be fitted to poles of any desired length. A pole hook, which can be made by any blacksmith, is often useful for removing the small dead branches. For lowering large limbs a set of blocks is necessary, and in the felling of trees a cross-cut saw is indispensable. Ropes of various sizes, iron wedges for felling trees, axes, mallets and chisels, ladders, spurs for climbing, etc., are also indispensable.

The above are the most essential tools for pruning shade trees, although there are others which are extremely useful and time saving.

Healing of Wounds.

A protective feature characteristic of all plants is well illustrated in the healing of wounds. The healing tissues (callus) in a tree are the cambium and adjacent meristematic cells located between the wood and the outer bark. The plastic substances which provide the material for growth and healing are manufactured in the leaf, and are transferred through certain tissues of the inner bark (phloem) adjacent to the cambium to various parts of the tree. When the tree is girdled or the bark removed no growth takes place below the girdling because the channels of transportation are destroyed.

FIG. 25. — Healing of wound. Most active healing follows most direct lines of transference of plastic materials.

In some young plants the pith cells possess the power to form a callus, but such cases are rare and of little importance. The younger the tissue or organ the more quickly it will heal, providing other things are favorable, and vigorous trees will form a callus much more quickly than old or weak ones. Since the plastic substances are manufactured in the leaf, and since it is these substances which are necessary for the development of healing tissue, it is only when

wounds are located along the line of transference of the plastic substance that they develop healing tissue. The sides of a circular wound as a rule heal over most rapidly because they are most directly in the channels of the transference of the plastic substances, and the top and bottom of the wound heal more slowly. When these facts are borne in mind it will be seen that a proper shaping of the wound is important for the development of a more or less even callus formation. (See Fig. 25.) Cuts made near large, leafy branches are more likely to heal quickly than those near small ones, for the reason that a larger amount of the plastic materials is available.

To facilitate healing, recourse is occasionally made to cutting the bark smooth around the stumps of the removed limbs, and it is also claimed that after the callus is well started a recutting of the surface stimulates its growth.

Moisture is said to stimulate the growth of the callus, and the old practice of covering the wound with a mixture of cow manure, clay and lime had this object in view.

Disinfectants for Wounds and Cavities.

There are many erroneous ideas concerning the effectiveness of disinfectants and their use in general. This is particularly true of disinfecting materials used in tree work. Because a certain disinfectant is used

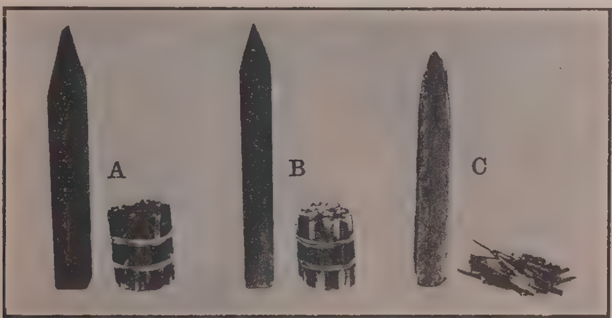

FIG. 26.—Effects of antiseptic treatment of wood in soil two years: (*a*) treated with Carbolineum; (*b*) creosote; (*c*) untreated. Little difference between (*a*) and (*b*); in (*c*) practically all decayed and about 50 per cent. completely.

successfully for one purpose it does not follow that it is applicable to all. As a matter of fact, all disinfectants are limited in their usefulness owing to the great variation existing in organisms as regards amenability to treatment by chemical substances. Disinfectants, therefore, possess specific rather than general properties, which are determined by many different factors. Copper sulfate, for example, is remarkably effective

when applied to reservoirs, ponds, etc., for cleaning out objectionable growths of many kinds, even when used at 1 to 1,000,000 parts or at 1 to 10,000,000 parts; while to be effective against the common blue mold, *Penicillium*, which is often found in the wood of dead trees, it requires a solution of about 1 to 30, or several thousand times stronger.

In the disinfection of wood tissues the following points should be considered. The disinfectant should be capable of penetrating wood tissues. An oily substance, which has more penetrating power, is far better adapted to this purpose than a watery solution. The substance should be only slightly volatile and should keep its original form, or at any rate its antiseptic properties, indefinitely. Copper sulfate, corrosive sublimate, formalin, lime and sulfur, and Bordeaux mixture have been used as disinfectants and preservatives in the treatment of tree cavities, scars and wounds, and while all of the above-named substances have specific disinfecting properties it does not necessarily follow that they are adapted to wood tissues.

FIG. 27. — Inferior mechanical work. Iron band too low for best support, and also causing girdling.

The above-named substances possess limited powers of penetration, and have little or no permanent antiseptic value when applied to tree wounds. Coal tar is also objectionable because of its lack of penetrating power, and because it loses its fungicidal value as it becomes hard. A thick, nonpenetrating material applied to wood is not only of no value, but becomes an injurious agent, as shown by the treatment of shingles on roofs. The old practice of tarring roofs simply induced decay because the tar coating conserved moisture in the shingles, and decay followed more rapidly than in the untreated shingles. Coal tar, however, is useful in covering surfaces previously treated antiseptically. In fact, the use of creosote followed by coal tar constitutes one of the best scientific treatments known, especially for exposed wounds. On the other hand, paint which contains plenty of oil is valuable, as has been proved by long years of experience. It lacks durability however.

Shellac dissolved in alcohol and applied to wounds is serviceable for filling the pores of wood and preventing decay, and hence is of some value as a wound dressing. Gas tar and liquid asphaltum are also sometimes used to cover wounds, and there are specially prepared paints and other substances for use as wound dressings. Even common painter's oil is excellent for the treatment of wounds, as it prevents checking of

the wood tissue. As the transpiration current remains practically normal because checking of the wood is prevented, trees will support a large amount of foliage even when badly girdled. Painter's oil is especially suitable for bark wounds. These should be first properly shaped and their surfaces scraped before applying the oil or other substances. Practically all disinfectants injure delicate tissue such as the cambium layer, but it should be borne in mind that the cambium always dies back to a certain extent when exposed to the air, and more of this dying back results from dessication than from the use of antiseptics. All antiseptics must be used with judgment, especially when the vital tissues are likely to be seriously injured by their use.

Chaining and Bolting Trees.

It often becomes necessary to bolt or chain trees to render them more secure and to prevent injury and disfiguration. As this process is not necessarily always an expensive one it should be much more commonly employed, many valuable trees having been made practically worthless by the loss of large limbs during wind storms, etc. Although the elm is a very tenacious tree with wood that is very difficult to work up into fuel, it is very likely to split. For this reason it is advisable to chain and bolt elms and any other trees which show a tendency to weakness. For an outlay of from $10 to $15 it is often possible to save a tree worth $150 to $200 from destruction.

FIG. 28. — Girdling by chain placed around tree.

Different devices are employed for strengthening trees. Some of these are objectionable and do more harm than good. It has been a common practice to place chains around limbs to prevent their splitting, but as the tree develops the chains become imbedded in the bark, resulting in partial girdling, and ultimately disfiguring and injuring the tree.

Another equally objectionable method which invariably results in girdling consists in placing strong bands of iron around limbs and trunks. For making trees more secure some prefer to use an iron rod rather than a chain, and although both have their place, in our estimation the chain system is the better for most purposes. If it is necessary to fasten branches near the point of forking where swaying is limited an iron rod is preferable; but for connecting limbs a few feet apart more or less remote from their junction with one another (where swaying is more pronounced) the chain method is superior. A rod is likely to break when the tree is swayed by the wind owing to its rigidity, whereas a chain, which is flexible, will stand the strain better. Moreover, a chain is easier to place than a solid rod, as less attention has to be given to boring the holes. However, if

one or two links are placed in the rod, as is sometimes done, this difficulty is of course obviated to some extent.

Galvanized stranded guy wire or cables, such as are employed by public-service corporations for anchoring their poles, are superior to either chains or rods for holding in place defective limbs and branches, and are far more pleasing to the eye. These wire cables may be obtained in various sizes and are much cheaper and stronger than chains. Their tensile strength varies according to size and quality from a few thousand to several thousand pounds, but the more flexible cables are best suited to this work. A chain is as strong as its weakest link or member, which sometimes may be very weak, whereas a stranded wire cable is much more homogeneous in its construction and less likely to break. The strain which it is necessary to overcome in swaying trees is often very great, and we have known many chains to break when the links were composed of three-eighths or five-eighths inch iron. Wire cables and chains are usually used with eyebolts, provided with washer and nuts, but the eyebolt often constitutes the weakest feature. It is therefore important that only the best quality of iron be used in the construction of eyebolts. Moreover, work of this nature demands skillful blacksmithing.

FIG. 29. — Showing combination of bolting and banding method which caused girdling to the tree.

FIG. 30. — Illustrating the combination banding and bolting method. It is extremely faulty in all respects.

When stranded cables are used the eyebolt method is sometimes dispensed with. In this case the wire passes through a hole in the tree and around an embedded piece of iron. The wire method is also valuable in temporarily rendering safe weak or dangerous limbs, and in anchoring more or less decrepit trees to strong supports.

Most of the chaining, bolting, etc., observed in trees follows extremely poor mechanical principles. The chains or bolts are often too small, and are seldom placed advantageously as regards leverage, the majority being placed too low or too near the crotch of the tree, thus requiring too much strain to be overcome. Where large limbs are involved, most eyebolts should be 1 inch in diameter and extend through the tree, these being supplied with a 3 or 4 inch washer and nut. The practice of screwing eyebolts or hooks into a tree for a short distance for the purpose of attaching a chain is bad, since they may be pulled out or broken off with the

slightest strain, and only a bolt passing through the tree, provided with a washer and nut, is suitable for such work. If stranded wire is employed it may pass around an imbedded iron bolt at the back side of the limbs.

In any system of strengthening trees, whether by wires or other methods, the best mechanical principles should be employed and a careful estimate made of the amount of load that must be carried; also the proper angle of attachment, etc. The amount of strain to overcome in wiring trees is invariably underestimated, even with an ordinary amount of swaying. During severe tempests hardly any tree is safe, a twisting air movement of great velocity acting as a severe strain. It is always wise to have the chain or wire used far within the limit of safety. Since the limbs or branches of a tree have a tendency to move inwards during cold weather, causing chains and wires to become slack, all wires should be drawn tight at their installation.

FIG. 31. — Iron band around limbs of tree. An objectionable method.

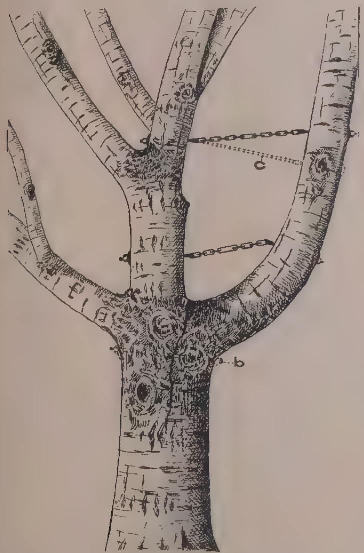

FIG. 32. — Improper method of chaining tree. Dotted lines show more effective method: (*b*) bolt, (*c*) chain. All chains, however, too low.

In many cases of chaining and bolting the washer and nut are placed on the outside of the bark, and often no attempt is made to cut off the ends of the bolts. The unsightliness of this method makes it objectionable. It is better to cover the nut and washer, which may be done by countersinking them into the wood of the tree by means of a gauge or extension bit, and the free ends of the bolts should be cut off close to the nuts. The washer and nut should be well imbedded in

thick paint or coal tar, and either elastic or Portland cement used to cover them, allowing the cement to come flush with the exterior surface of the wood. By this method the ends of the bolt, washer and nut are covered, and the scar produced by this operation will heal over in a short time, leaving no trace.[1]

FIG. 33. — Chain and bolt method of supporting limbs.

The poles of public service corporations are often attached to trees by guy wires, and care should be taken to prevent injury to the tree from girdling, etc. A large wire loop placed round a tree and properly insulated from the trunk by special hard wood blocks is usually harmless, and is more desirable on streets than other often unsightly methods of anchoring poles. These blocks may be made from oak, and should be 2 inches wide, $1\frac{1}{2}$ inches thick and 8 or 10 inches long for heavy wires. They should be provided with a shallow groove to take the wire, the groove being made a trifle narrower than the wire to insure a tight fit. (See Fig. 42.)

Treating Decayed Cavities, Fillings, etc.

Decayed cavities in trees are very undesirable since any fungi and insects which may be present will extend their range of activity, causing decay and shortening the life of the tree. Cavities result from poor pruning of limbs, the breaking off of branches,

FIG. 34. — Tree properly bolted; washer countersunk and imbedded in cement.

[1] The weight of a limb may be roughly obtained by multiplying the average diameter by the length. This calculation should include the numerous small branches, limbs, etc.

According to Prof. C. S. Sargent (Woods of the United States, 1885), the weight of a cubic foot of elm wood is 40.55 pounds when dried at 100° C., and according to W. S. Clark (32d Rept. Mass. State Board of Agriculture for 1874) the amount of water in elm wood varies from 40 to 60 per cent.; thus a cubic foot of green elm wood would equal about 60 pounds. A limb 40 feet long with an average diameter of 8 inches would weigh about 840 pounds, and a section about 34 inches long would equal 1 cubic foot. Of course the leverage which must be overcome is determined by angles of the limb and point of attachment of the chain or wire. (See Fig. 36.)

and other injuries which are not followed by proper treatment at the time.

The treatment of cavities naturally involves some expense, but if a tree is of any value it is worth treating, even though its value may be sentimental in nature. There are many trees which to the casual observer would appear to be of little consequence, but the associations connected with them may be highly cherished. Then, again, the location is often important. A tree may furnish shade which cannot be dispensed with, and even if old and decayed it is often more satisfactory to treat it than to wait for a new tree to grow.

The rationale underlying the cleaning and filling of cavities is similar to that in dentistry. If the work is properly done, and if antiseptic conditions are secured, the length of a tree's life may be extended.

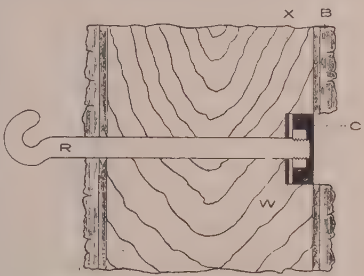

FIG. 35. — Longitudinal section of limb, showing method of bolting. B, bark; X, wood; R, bolt; W, washer; C, cement.

For centuries trees have been treated in various ways. Cavities have been filled with wood, brick, stone, cement and other substances, but as a rule much of this earlier work was very crude in nature, and has accomplished little or nothing toward the prevention of decay. During the past few years, however, more scientific attention has been given to the treatment of decayed cavities in trees, and many good examples may be seen here and there, although it must be confessed that as yet the work is in more or less of an experimental stage.[1]

As has been said, the object of treating decayed cavities is to prevent further decay and to prolong the life of the tree; but there is no particular reason why people should spend one or two thousand dollars on a single tree for repair work when it is possible and certainly more reasonable to transplant a larger and better one for two or three hundred dollars.

The first step in the treatment of cavities is to remove all decayed and infected tissue, which is done by a thorough cleaning out of the cavity.

Second, to treat antiseptically all the exposed tissues which are susceptible to decay, preventing further disintegration. The disinfecting

[1] The writer's first attempt to establish a course covering shade-tree management was in 1895 although the research work concerning shade-tree problems antedated this period. At that time there was little material of a reliable nature at hand touching upon the many shade-tree problems which were continually coming up, and it was practically impossible to organize a course of study relative to the subject which would be of any great practical, scientific or pedagogical value. It was, therefore, apparent from the first that an extensive course of study covering this subject, to be of practical value, would require a scientific basis. However, the numerous investigations carried on during recent years relating to shade-tree problems have placed this subject on an entirely different basis, although there is still great opportunity for further research work along these lines.

substance should be one which can safely be used and still be permanently effective. Creosote is one of the best antiseptics because it possesses superior properties for penetrating wood, and is quite permanent as a disinfectant. In some cavity work this is as far as it is necessary to proceed, especially in the treatment of old, weak, decrepit trees which at most have only a brief period to live, and when there is already considerable strengthening tissue owing to the inward growth of the callus and wood. It is often inadvisable to remove this strengthening tissue and fill the cavity. (See Fig. 43.)

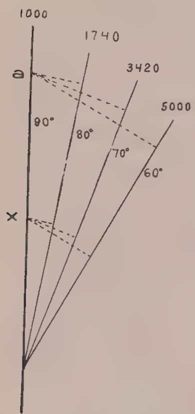

FIG. 36. — Showing relative strain in pounds on wire or chain holding limbs at different angles. The strain at x would be twice as much as at a.

Third, to cover the orifice or opening of the cavity to direct the growth of the callus or healing tissue. However, trees are seldom if ever strengthened by fillings; on the other hand, they are too often weakened by overloading, although ultimately, as new tissue develops over the surface of the filling, strengthening may follow as a result of growth.

Innumerable instances may be observed of positively injurious tree repair work which has been done by incompetent men, some of whom are downright scoundrels; and many trees have come to a sad end from overloading with heavy concrete. Sometimes the tree collapses before the contractor actually finishes the work, in which case litigation usually follows.

FIG. 37. — Illustrating a faulty method of chaining trees.

The writer has had many opportunities to observe cavity work in trees. Some of these cavities were treated forty years ago, and when thorough cleaning and antiseptic treatment were given the cavities, decay has been arrested to a very remarkable extent. Even some of the work done by ignorant men and amateurs, who are unable to distinguish between normal and infected wood, has been effective in arresting decay, although only the punk and discolored tissue is usually removed from the cavities.

While some progress has been made in cavity treatment during recent years, the greatest drawback to the development of a more scientific and intelligent method of treatment is ignorance and incompetency on the part of those undertaking such

work. The use of worthless disinfectants, the improper shaping of the cavity opening, and many other wrong methods show a total disregard for the first principles of scientific treatment and for common sense. It is unfortunate that so many have undertaken to do tree repair work with-

FIG. 38. — Showing cross-section illustrating the eyebolt and the stranded wire method of attachment. (Compare Fig. 39.)

out adequate training or special aptitude for it. There are innumerable so-called "tree experts," "tree specialists," etc., whose whole experience consists in having filled one or two tree cavities. They possess little or no knowledge of trees or tree problems. Too much stress is also laid on the external appearance and smoothness of their cavity work. They seemingly fail to realize that the scientific treatment of a wound or cavity is fully as important as its appearance when done.

FIG. 39. — Illustrating eyebolt and stranded wire method of attachment.

The principal advance in cavity work has consisted in more thorough cleaning and more effective antiseptic treatment, and some improvement has been made in the technique of cement work. However, these innovations are of minor importance, considering the extent of the work done and the opportunities offered for improvement in the scientific and rational treatment of cavities.

Methods of treating Cavities. — The greatest need in tree cavity work at the present time is more suitable material and improvement in methods of doing the work. There is no reason why a cavity should be filled, — in fact, there are reasons why it should not. The principal problems associated with cavity work are those involving the eliminating of fillings of all descriptions. A durable material with physical properties similar to those of the tree to direct the callus growth must also be found.

There are several methods for the treatment of cavities, some of which were first used years ago. Brick and stone laid in cement have been used

as a filling to cover the cavity opening, and some years ago use was made of irregular pieces of untreated wood for filling cavities. However, cement in different forms has been most frequently employed for cavity fillings, and various metals have been used as a covering for the cavity opening, Use has also been made of wire mesh covered with elastic cement; combinations of asphalt and sawdust; paraffine and sawdust; wood pulp and cement; excelsior and asphalt; sawdust, tar and oakum; certain composite substances like papier-maché; special floor cements; and chemically treated wooden blocks.

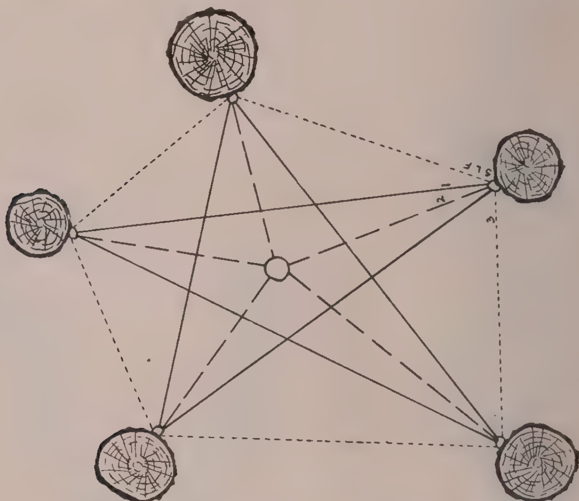

FIG. 40.—Different methods of fastening branches. The solid lines represent the best method; dotted lines inferior methods.

Various disinfectants, such as copper sulfate, corrosive sublimate, Bordeaux mixture, kerosene, formalin, carbolineum, coal tar, creosote, etc., have been employed for cavity work, but some of them are poorly adapted for the purpose. Creosote and carbolineum are similar in nature, and are the best materials for disinfecting cavities. The former apparently possesses greater power of penetration than the latter, although carbolineum seems to form a more permanent external covering than creosote. (See Fig. 26.) Owing to the slow penetration of all disinfectants into moist wood, more than one treatment is needed, and if the cavity is left open for a while before receiving later treatments, so much the better.

Although there have been complaints that creosote injures trees, we have never observed any such injury, notwithstanding the fact that we have treated cavities within 1 inch of the vital area. In all instances

observed, where injury was reported from the use of this substance, the pathological conditions were due to other causes, and were present previous to the time of the repair work.

The expense involved in the different methods of treating cavities varies considerably, and it is not well to increase it unnecessarily. However, if a tree is worth treating the work should be done well, and the more costly methods need not be condemned if they achieve superior results. Before an attempt is made to repair a tree a thorough examination should be made, but this is seldom done. Often a considerable portion of a tree above and below the ground may be dead without the fact being noticeable to the casual observer. A careful examination would reveal the fact that the tree is not worth expensive treatment.

FIG. 41.—Bolt passing through a tree with large square washer. A smaller round one, represented by the white circle, is a more desirable form to use.

Shaping the Cavity.—The shape of the cavity interior is determined largely by the necessary removal of the decayed material. As the decay of the heartwood is usually more extensive than that of the sapwood, the interior dimensions of a cavity are usually greater than those of the orifice or opening. A shoulder is thus formed, and this is of great advantage when cement and other substances are used in filling. In cases

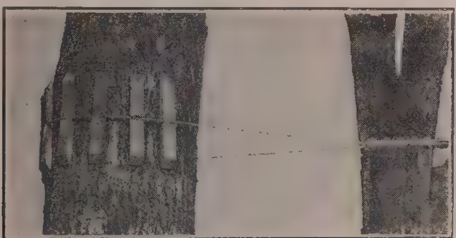

FIG. 42.—Least objectionable method of anchoring guy wires to trees.

where there is no shoulder, spikes may be driven into the wood or iron bolts used, or grooves in the wood may be chiseled out to anchor the filling substance more thoroughly and to prevent its dislocation. But the shaping of the cavity opening or orifice is most important, the main object in filling a cavity or covering its opening being to direct the callus

or healing tissue. It is therefore essential that the shape of the cavity opening conform to the path of the translocated plastic substances of the tree. These are confined to the phloëm, or inner bark. The sides of the cavity opening should, in a general way, conform; and the less the irregularity of the edges of the opening the better.

FIG. 43. — Demonstrating the object of treating cavities. Upper figure shows cavity of long standing, with callus curved in, which, if it had been treated, would be as represented below.

If the cavity is above the surface of the ground the apex and base of the opening should never be truncated or flattened, but should be apiculate or pointed. There is no particular objection, however, to having the opening of the cavity perfectly square or rectangular if the bark is removed above and below the opening and brought to a pointed or rounded termination. (See Fig. 49.) This allows the healing tissue to form regularly and uniformly over the outside of the cavity. This also holds true in the treatment of scars and abrasions on trees. After removing the bark the wood should be scraped and treated as with any wound.

Concrete Fillings. — Concrete has been used more largely than any other substance for filling cavities in trees, but its physical properties are so unlike those of wood that it has never been regarded by competent authorities as a suitable material for work of this nature. By some workers its use has only been tolerated until something better could be substituted.

Some of the numerous objections to be raised against filling cavities with cement are as follows: —

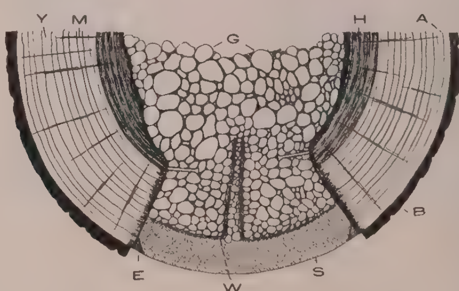

FIG. 44. — Cross-section of filled cavity showing one method of treatment. B, bark; Y, sapwood; M, medullary rays; H, heartwood; A, annual rings, G, grouting; S, cement surface covering; W, wire re-enforcement; E, elastic cement. Inferior to the dry cement methods now used.

(*a*) Cement cannot accommodate itself to the constant swaying movements of trees. As a consequence the fillings are likely to become displaced and crack, although this is not so often the case with fillings low in the tree. This unavoidable cracking of the cement renders it extremely unsuitable for use in cavities.

(*b*) Cement upon drying shrinks from the wood, furnishing an entrance for water, frost and injurious organisms which may cause damage if the conditions are favorable.

(*c*) It is practically impossible to stop bleeding from a cavity that has been filled with cement. This exudating sap or "slimeflux," which is not uncommon in trees, discolors the bark and in some cases injures the underlying tissue.

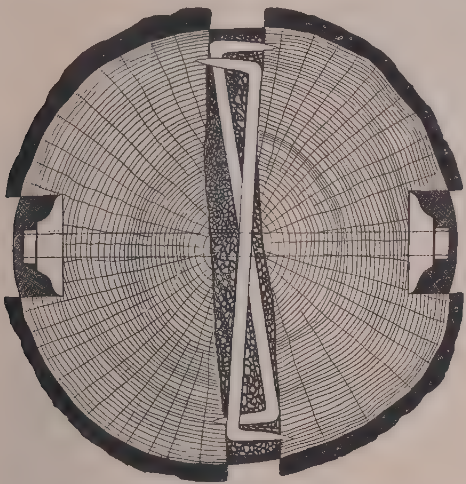

FIG. 45.—Cross-section of split tree with bolt and countersunk nuts and washers and iron braces to obviate movement. Instead of cement, wooden blocks should be employed to cover the opening of the cavity.

(*d*) There is nothing to be gained from filling a tree cavity with cement or any material. The chief object of filling is to protect the healing tissue or callus of the tree after the cavity has been thoroughly cleaned and disinfected, and this can be accomplished by other methods.

(*e*) Cement does not in any case strengthen the tree; on the contrary, it often proves weakening because of its cumbersome and quite unnecessary weight. It is not adapted to horizontal cavities, which are difficult to seal sufficiently to prevent trouble from water, etc.

(*f*) The several schemes devised to increase the efficiency of cement fillings, such as re-enforcing with iron, wire, etc., covering the cement

surface with metal, the use of elastic material and special grooves, laying the cement in sections, and many others, have not proved of any material value in solving the problem.

FIG. 46. — Cement-filled cavity favorably shaped for healing over.

(*g*) The tissues back of a cavity are rendered more susceptible to decay by the cement filling. This is especially true if proper antiseptic treatment is not given, or if the cavity is not thoroughly cleaned.

From the various objections given it follows that it is often better to leave the cavity open, or merely to cover the same, than to fill with cement.

Several methods have been employed for the use of cement, and a detailed description of all of them is hardly worth while. It has been extensively employed as a filling, and also as a covering for the cavity opening, in which case the main cavity itself would be left unfilled. In most of the older work in filling cavities with cement the opening of the cavity was boarded up and grouting of a more or less soft consistency, consisting of 1 part cement to 5 or 8 of sand, gravel or other material, was poured in. When this was partially set the boards were removed and the surface of the grouting was coated with about 1 part cement to 2 parts sand, this extending to the outer edges of the wood and conforming to the general contour of the tree. In other cases cement in the proportion of 1 part to 2 or 3 parts of sand has been used in a relatively dry form, applied in small quantities, and thoroughly tamped. This method does not require the use of boards at the cavity opening, as the cement, which is uniform throughout, is gradually built up until the filling process is completed. The outer surface conforms to the general contour of the tree. The use of relatively dry cement has proved more desirable for cavity work than grouting, followed by a surface covering of a different consistency, and has done away with considerable of the cracking and dislodgment of cement which followed surface covering over grouting. In cavity work of all kinds where cement is used, nails, spikes, wires, iron rods and bolts, wire mesh,

FIG. 47. — Cement-filled cavity with bolt.

etc., have been used freely in numerous ways for re-enforcing. When the cavity has no "shoulders" to hold the cement in place, spikes driven into the wood are effective in anchoring the cement, and we have observed such fillings to remain undisturbed for many years.

Any filling substance or covering of a cavity should always come flush with the exterior of the wood. For this purpose it is best to cut the bark back as little as possible to expose the edge of the wood to view. Special grooves cut in the wood of the cavity just anterior to the outer edge of the wood have been used with the idea of directing the flow of surface water which may enter the cavity, or that arising from the interior caused by bleeding, but these grooves have not proved of practical value. A V-shaped groove cut in the edges of the cement before hardening, filled with elastic cement to prevent water from entering, is sometimes used. As there is always more or less separation of the cement from the wood after setting or hardening use has been made of thick elastic substances to cover the surface of the cavity to make the contact more complete.

FIG. 48. — Stump growth of white oak with cavity cleaned and treated with creosote and filled with cement. Edge of cavity effectively sealed with elastic cement.

Sectional Concrete Fillings. — The writer first experimented with sectional concrete fillings in 1902 and 1903, and has at different times since suggested this method of filling cavities to those seeking to avoid cracking of the cement where considerable movement exists. In our original experiments the cement was laid in sections, each section being allowed to become set or hardened before another was put on. The sections were further separated from one another by the use of such substances as cardboard or tarred paper, fiberoid, elastic cement or wire mesh. Our idea in developing the use of sectional work was to eliminate cracking of the cement which so commonly follows the use of this substance, and the purpose of using more or less elastic substances between the sections was to form a bed for each section or independent unit to move upon during swaying without causing chipping of the edges of the sectional blocks. The sectional method of filling has been employed quite extensively within the last six years, and at present it constitutes the best method of employing concrete cement in tree cavities.

In some of this work the sections are bolted to the tree, thus restricting independent movement to a certain extent by anchoring the sections. In consequence of this anchoring the sections load the tree with weight,

whereas in basal cavities if not anchored they would not, and with the use of entirely independent sections the movements of cement would be slightly different.

The first to use sectional concrete in tree cavities with bolted sections was probably the late city forester W. F. Gale of Springfield, about 1906. Mr. Gale employed two cross bolts to each section, the sections being about 20 inches long and separated in part by wire mesh. After the cement had sufficiently hardened the bolts were tightened to separate the sections or individual units still further. At the present time tarred paper is usually employed between sections, but where there is much movement this substance is hardly thick enough, especially on the outer edges, to prevent chipping. We had this feature in mind in our original

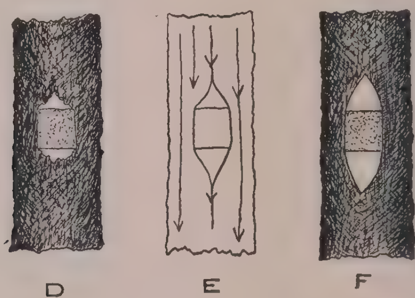

FIG. 49. — Showing a square cavity filled with cement. D, disintegrated bark above and below the filling; E, general path of plastic or healing substances; F, bark cut to point to accommodate the process of healing and conforming with the path of healing substances.

sectional work. With the judicious use of iron bolts (which should in our opinion be independent of the sections) in order to secure rigidity, the sectional cement method has proved superior to the older methods of filling cavities, since it has done away with much miscellaneous cracking and dislodgment of fillings.

Much improvement in the quality of the cement work done on trees has been made within the last few years, especially in cement technique, and some of the Portland cement surface in cavities is excellent. A great deal of puttering and detail work such as thorough tamping and troweling of the cement is often done in tree cavity work, especially when the contract is for work by the hour. Thorough tamping and troweling improve the cement, and as a result of this frequent time-killing process practiced by certain unscrupulous workers some of the best individual examples of cement technique may be found in trees. While the sectional method of filling cavities with cement has caused

some advance in cavity cement work, it does not solve the problem of treating cavities. In many cases of sectional work it is an absolute failure. This is true especially when there is too much swaying or when the tree cannot stand the load, or when there is too much crushing force, as in narrow cavities. All concrete work on trees is better adapted to cavities located near the ground or below the surface than to high cavities where swaying constitutes an important factor, and where an increase in the load which a tree is obliged to carry is objectionable.

FIG. 50. — Concrete filling built in sections. (From "Tree Talk.")

Concrete Coverings for the Cavity Opening. — Concrete may be used to advantage as a covering for cavity openings to form a surface for directing the healing tissue. With this method the interior of the cavity is left unfilled, and if the cement is properly reenforced with iron the scheme is practicable and possesses many advantages. The writer has treated some large cavities by this method, and it has proved as satisfactory as solid fillings. Considerable cement is also saved. (See Figs. 51 and 52.)

Metal Coverings. — Metal was much used formerly, and is to some extent to-day, to cover the openings of cavities, and some very creditable work has been done in this line. For this purpose tin or zinc is cut and shaped to meet the requirements of the cavity opening, and after some of the bark has been cut away the metal is securely fastened to the sap wood with tacks. With this method of treating cavities the usual cleaning and disinfecting are done, but the cavity itself is left unfilled.

The principle underlying this method is good, but metal has not proved a durable covering, nor are its physical properties suitable to work of this nature. It is affected too greatly by changes in temperature, which

has a tendency to displace the tacks; consequently the metal covering becomes loose and valueless in a short time. Metal is inclined to deteriorate in a few years, and cannot accommodate itself to much movement in the tree unless it is used in sections and imbricated or overlapped like shingles.

FIG. 51. — Chestnut tree cavity resulting from stump growth, with cavity covering of cement about 6 inches thick. (See Fig. 52.)

Sometimes metal is used to cover cement-filled cavities, but this is of no particular value, and does not improve the appearance of the tree. The principal purpose in using it over cement is to cover the cracks, and when used in connection with iron bands over the surface it is supposed to help hold the cement in place. In some cases where metal is used in this way it is lapped over on the bark 4 or 5 inches, but this destroys the underlying tissues and arrests their future development, thus defeating one of the main objects of treating cavities, — *i.e.*, encouraging and directing the healing tissue or callus formation.

Elastic Cement. — Elastic cement, such as is employed by slaters, has been used for some years in tree repair work, and was recommended for this purpose by the Massachusetts Forestry Association about 1900. Its principal value in tree repair work consists in its elastic properties and its adaptability to places where there is considerable movement. It is too expensive for use in large cavities, costing from 4 to 15 cents per pound, but it has been employed to some extent for filling small spaces and also as a thin covering for cavity openings. In the latter case wire mesh is strung across the cavity opening, the wire mesh being re-enforced with iron and shaped to conform to the outer contour of the tree; and the elastic cement is plastered on the mesh. (See Figs. 54 and 55.)

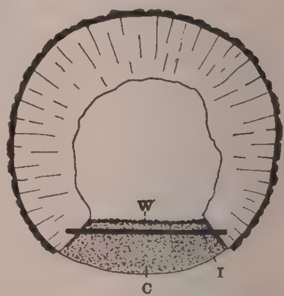

FIG. 52. — Illustrating cross-section of the cement surface covering to cavity shown in Fig. 51. W, wire stapled to sides of cavity; I, iron re-enforcing; C, cement.

This method of treating cavities has been especially recommended by Mr. L. F. Prouty, associated with the city forestry department, Spring-

field, Mass., who has made quite a little use of elastic cement for cavity work. One of the drawbacks in the use of this substance for tree work is that it does not harden sufficiently, the surface easily becoming disfigured. On the other hand, it is valuable for cavities in high swaying trunks and limbs of trees, and especially for cavities with horizontal openings.

FIG. 53. — Cavity in apple tree cleaned out, treated antiseptically, and surface covered with tin.

Wood pulp with a thin facing of Portland cement has also been employed for covering the openings of cavities.

Asphalt Fillings. — During the last twenty years numerous attempts have been made to use asphalt in tree repair work, and more recently it has been employed in combination with other substances. Asphalt and sawdust have been used for cavity work by Mr. John Boddy,[1] city forester of Cleveland, Ohio. For cavities in swaying branches he uses 1 part asphalt to 3 or 4 parts sawdust, and for other cavities 1 part asphalt to 5 or 6 parts sawdust. The sawdust is stirred into the hot asphaltum until the desired consistency is obtained, and the mixture while still hot is put into the cavities with tools smeared with crude oil. Mr. Boddy recommends a grade of asphaltum termed "Byerlyte" as best suited for this purpose. This is derived from refining petroleum with an asphaltum basis, and is the same as that used on street pavements. The mixture of asphaltum and sawdust is better adapted physically to the movements of the trees than the more rigid Portland cement.

FIG. 54. — Elastic cement covering of cavity opening. Wire mesh only supports the thin covering of cement. (After L. F. Prouty.)

[1] Ohio Agr. Exp. Sta. Cir. No. 150, June 11, 1915.

Another method of treating tree cavities with the use of asphalt has been devised and described by Elbert Peets. This consists of using brickets or units composed of asphaltum and excelsior. These brickets are employed as a covering to the outer surface of the cavity, and are cemented together with asphaltum. The brickets are secured to the side of the cavity opening by spikes, and are held in place by iron re-enforcements, the portion of the cavity back of the brickets being filled with sawdust, cinders or other material. An especially commendable feature of this method is the unit system employed, and the adaptability of the material to the movements of trees. On the other hand, asphaltum is not a convenient substance to use because it has to be heated. The same objections to completely filling a cavity apply also to asphaltum, although with the use of this material such a practice may not always be necessary.

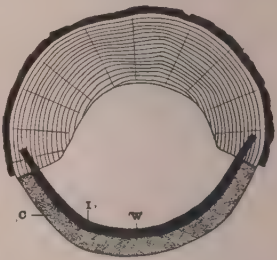

FIG. 55. — Section of tree with cavity illustrating wire and elastic cement method of covering opening. C, elastic cement; W, wire mesh; I, iron re-enforcements.

Wooden Block Method. — This method of sealing cavities (invented by the writer) has been in use only recently. It consists in the use of chemically treated wooden blocks to cover the opening of the cavities, and makes filling unnecessary. The blocks are of different sizes. Each one constitutes a homogeneous structural unit composed of various cellular elements, similar to those in trees. With this method, as in others, the cavities are cleaned and treated antiseptically, the blocks being used simply to cover the orifice of the cavity and to direct the growth of the callus or healing tissue.

FIG. 56. — Chemically treated wooden block covering of cavity opening, with back re-enforcements of wood. The normal growth of the callus is not disturbed. (After J. A. Davis, City Forester, Springfield.)

The advantage of wooden blocks for cavity work consists in the fact that the blocks are composed of the same type of element as found in trees. The geometrical arrangement of the various elements, as well as their chemical composition and molecular structure, is similar; moreover, the physical properties — rigidity, elasticity, etc. — are practically identical. The various movements in the cavities of trees resulting from variation in temperature, moisture, barometrical influence, etc., may be better conformed to by the use of this material than by any other yet employed for the cavity treatment.

The blocks should be arranged in the cavity opening so that the radial and tangential surfaces of the structural elements in the blocks coincide in general with those in the tree. It is not necessary to lay the blocks in cement, but in some cases painting the surfaces which will come into contact with one another with an elastic cement is of advantage. The blocks are fastened to the tree by means of special iron braces and held securely by iron re-enforcements. Besides being especially adapted, owing to their physical properties, to use in trees, such blocks are durable, light and easy to fit, and are better adapted to swaying movements and crushing pressure found in narrow cavities than rigid or less plastic substances such as have been used heretofore. The disagreeable and injurious effects arising from bleeding may be taken care of by this method of cavity treatment, and constructive work may be done in winter as well as in summer.

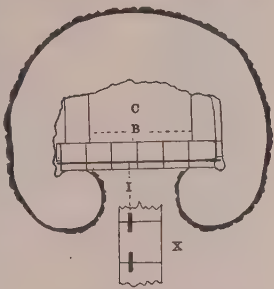

FIG. 57. — Cross-section of illustration shown in Fig. 56. C, cavity; B, chemically treated blocks; I, iron re-enforcement in grooves; X, longitudinal section of blocks.

TREE GUARDS.

There is almost no end to the types of tree guards used to protect trees. Some of these are good and others are of little value. The purpose of a

FIG. 58. — Different types of tree guards: 1, wooden strips nailed to a tree; 2, wooden strips nailed to a tree and banded with iron; 3, old type of wooden tree guard; 4, wooden strips banded with iron tightly to the trunk of the tree; 5, similar to 4; all objectionable types.

tree guard is protection, and the guard should cover the tree to a height of about $6\frac{1}{2}$ feet; it should be as light and as inconspicuous as is consistent with strength and protection; and should allow the tree ample

opportunity for growth without causing injury. The ideal tree guard is durable, easily placed and not easily displaced, inexpensive and neat in appearance. Some tree guards are attached to trees by means of staples or nails, but this method of attachment is objectionable. The old-fashioned tree guard made of wood usually became useless in a few years. However, while it may not have possessed much beauty or permanent utility, it at least showed a commendable spirit and desire for tree protection.

A very cheap and efficient tree guard is used to quite an extent in some places, and is known as the "Clinton Tree Guard." This guard is made of No. 15 galvanized wire, having a mesh three-fourths inch in diameter, all the wire contacts being soldered. This wire may be bought in strips of various widths from 12 to 48 inches, and cut off any length desired, 6 and $6\frac{1}{2}$ feet being the more usual lengths. Strips 12 to 18 inches wide are well suited for small trees. These are rolled up in cylindrical form of the desired diameter, and tied together by a few pieces of copper wire. To prevent the top of the tree guard from chafing the tree the top is protected by wiring through the rough edges of the guard a split piece of discarded rubber hose. Use is also made of insulated wires or springs placed diagonally through the top of the guard to hold it away from the tree. The great advantage of this guard is its cheapness, but it is made of heavy wire firmly woven, and answers the requirements very well. This wire is made by the Clinton Wire Company, Clinton, Mass., and costs about $4\frac{1}{2}$ cents per square foot. (See Fig. 60.)

FIG. 59.—Effectual tree guard used on Boston Common. The wire guard is re-enforced by pointed angle irons driven into the ground.

A re-enforced wire cloth guard manufactured by the Wright Wire Company, Worcester, Mass., has recently come into use. It is made from close mesh wire similar to that of the Clinton guard, but is re-enforced with flat metal strips. This re-enforcement is considered a valuable innovation because even heavy wire mesh is likely to crumple up with hard usage, and becomes ineffective as a tree guard. The re-enforced metal edges are provided with holes for the purpose of stapling the guard to large trees. (See Fig. 61.)

One of the neatest and most durable tree guards is shown in Fig. 59. It consists of an open-mesh, heavy-wired guard supported by a piece of angle iron on either side driven into the ground. The angle iron acts as a re-enforce-

ment and holds the guard in place. The use of any guard around trees is more or less of a nuisance, but at the present time they have to be applied to street trees. Planting inside of the sidewalk or on wide tree belts will obviate much of the use of tree guards in the future.

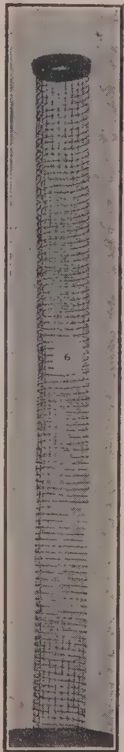

FIG. 60. — Clinton tree guard, with hose protection at top.

FERTILIZING TREES.

Trees, like agricultural crops, respond to tillage and treatment with fertilizers and manures, but there are only meager data relative to the specific effects of the various chemical constituents in fertilizers on shade trees. From what is known regarding their effects on other crops, and from their limited use on trees and shrubs, it is evident that they may be applied with a reasonable degree of success.

Wood ashes have been used to some extent for treating shade trees, also bone meal, nitrate of soda and potash in the form of muriate or sulfate. Any good complete fertilizers, such as those adapted to lawns, should prove valuable for trees. Wood ashes, which are not so easily obtained as formerly, are of benefit to lawns, and there is no reason why they should not prove suitable for trees. A certain amount of nitrate of soda, at the rate of 150 to 200 pounds per acre, may be used to good advantage, but care should always be used not to apply it too freely. The nitrate of soda stimulates wood production, and, like lime, helps to give a deeper color to the foliage; but an excess produces symptoms of malnutrition in many crops which usually takes the form of an abnormal development of foliage. Bone meal is slow to become available, but it does not injure plants when applied freely, and makes a good fertilizer. Pulverized sheep and cow manure are valuable lawn fertilizers, and even though the price is rather high for the plant food contained, they supply organic matter and therefore have an especially beneficial effect on the soil. They can be applied freely without danger of harm.

While trees will respond favorably to judicious treatment with fertilizers, it must be borne in mind that no fertilizer can take the place of cultivation. Fertilizers should be applied where the feeding roots are located, and these are confined largely to an area corresponding with the spread of the foliage and not close to the trunk of the tree, as imagined by many persons. This also holds true for tillage, *i.e.*, the whole area surrounding the tree should be cultivated to some distance beyond the spread of the foliage. As the tree develops in size the smaller feeding roots become less abundant near the base of the tree, although cultivation and feeding have a marked tendency to induce root development wherever they are

practiced. All fertilizers should be applied evenly. Spreading by hand is at best a poor method, as shown by the dark green plots of grass on lawns where nitrate of soda has been applied in this way; but when fertilizer spreaders cannot be had the hand method must be used. Another factor to be considered when applying fertilizers to lawn trees is that the grass roots will obtain their full share. Turning under the sod and cultivation of the soil around the tree is of the greatest importance from the very considerable amounts of organic matter added to the soil. Fertilizers applied under these conditions, or, far better, stable manure well incorporated into the soil at the rate of 20 to 30 cords per acre, are of the greatest benefit to the tree, even if it becomes necessary to reseed immediately. In cases where it is inconvenient or undesirable to disturb the soil around a tree, and when the application of fertilizer to the surface does not accomplish the desired results, holes 1 or 2 feet apart and 15 inches deep may be made with an iron bar and then filled at different times with a liquid fertilizer.

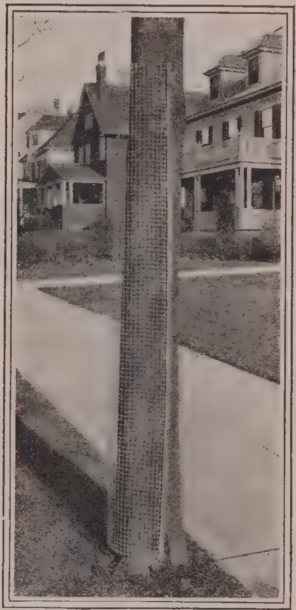

FIG. 61.— Re-enforced wire cloth tree guard, showing edge stiffening with nail holes for attaching to tree. (From the Wright Wire Company.)

There are a number of fertilizer mixtures prepared for shade trees that are undoubtedly of value, but some of them are apparently not based on any expert knowledge of the tree's special requirements.

DISEASES OF TREES.

Trees, like other living organisms, are very liable to attacks from disease, and a tree of any maturity is seldom found perfect in all respects. A disease may be defined as a disorder caused by any failure in or diversion of the normal physiological activities of the organism.

The diseases of plants with which plant pathologists have to deal may be divided into three classes: First, those caused by parasitic fungi; examples, — rust, smut, etc. Second, those brought about by functional irregularities which induce saprophytes (dead wood fungi) or parasites to thrive, such as "damping off," mildew, etc. Third, those of a purely functional nature, pathogenic organisms not necessarily being present; examples, — dropsy or œdema of tomatoes, malnutrition and others. All these types of diseases are found in trees, but the first and second are most common.

Diagnosis of Disease.

A successful diagnosis of disease necessitates a thorough knowledge of the normal and abnormal functions of the organism, together with an understanding of the specific reactions of the plant to various external and internal agencies or stimuli that may affect it. The specific reactions of plants are so little understood as compared with those of animals which have been studied for centuries that it often requires considerable study to make a complete and accurate diagnosis of some of the troubles affecting plants, especially without knowledge of the conditions to which they have been subject. Plants have their peculiarities, like animals, and the large number of different species which are normally adapted to a great variety of conditions and which are likely to be subject to disease renders the problem of diagnosis often quite difficult. The reactions of plants to stimuli are manifold, and much more depends upon the nature of the organisms stimulated, as regards the nature of the response, than upon the particular stimuli giving rise to the reaction. The same agency may produce a variety of reactions even in the same organism, and different agencies will often produce like effects.

FIG. 62. — Open mesh tree guard with protective springs at top. (From the Wright Wire Company.)

It might be difficult to tell whether a particular plant was affected by coal gas, hydrocyanic acid gas, burned sulfur, formalin vapor, or other gases without other evidence than that afforded by the plant, unless the observer possessed a special knowledge of the effect of these gases. But there are distinct symptoms displayed by plants which enable one, after much experience and careful investigation, to determine with some degree of accuracy the exact cause of injury resulting from injurious agencies.

In diagnosing diseases it is first necessary to distinguish between primary and secondary causes. A tree may be subject to borers and fungi, but these may not be the primary cause of the trouble; indeed, they are more often merely secondary effects. A tree may sometimes winterkill and become subject to fungi, but one would not be justified in diagnosing the case as injury from fungi, although in the diagnosis of disease secondary causes are often mistaken for primary ones. It should be borne in mind, however, that no plant ever dies without some definite cause. In deter-

mining the health condition of a tree it is important that all the factors in any way concerning it should be well understood; in other words, one should be able to judge of the degree of vigor possessed by the tree. A tree in a vigorous condition has a quite different appearance from one that is less thrifty. In the former case the bark has a certain color and other characteristics by which it is easily distinguished from those in a less healthy tree. This is also true of the branches, twigs and leaves as well as of the general habit of growth.

Finally, in all tree work it is essential that as thorough knowledge as possible should be secured of the structure and function of the tree, its normal and abnormal characteristics, and the causes responsible for health and disease. As a rule, tree workers have little idea of tree structure and function; consequently their diagnoses are seldom correct.

Fungous Diseases of Trees.

There are troubles of a serious nature affecting trees which are not associated with organisms; but by far the most numerous and troublesome diseases are caused by fungi, and occasionally by other types of organisms. The fungi responsible for decayed cavities do the most damage to trees.

There are a great number of leaf spots — *Septoria*, *Cercospora*, *Phyllosticta* and other genera — which affect both our native and introduced trees and shrubs, and mildews are found on almost every tree and shrub. Much careful investigation has been given to the control of plant diseases in general, and valuable results have been obtained from spraying and other methods of treatment. (See Treatment.) The fungous diseases of our agricultural crops have been thoroughly studied, and most of them are of enough importance to warrant systematic treatment every year; but a large number of the leaf spots affecting shade trees are not common enough to do any particular harm, and at least during the past many of them have not been considered worth serious study from the viewpoint of treatment.

Most of the fungi affecting leaves and branches are parasitic; a few are saprophytic, *i.e.*, attacking only dead tissue; while still other forms flourish either as parasites or saprophytes. The root-like mycelia of parasites in most cases penetrate the cells and rob them of nutriment. Often fungi cause distortion of the tissues so that galls and other abnormal growths are formed. They also have acquired the peculiar habit of secreting ferments that dissolve the cell walls. All fungi are capable of producing some injury, but economically considered, treatment is necessary only when the injury greatly retards the growth of the tree or seriously impairs its appearance.

Among some of the commoner forms of fungi that affect shade trees may be mentioned the following: —

Maple (*Acer*). — Leaf spot (*Phyllosticta acericola* C. & E.) forms irregular brownish spots on the leaves of the rock and white maples.

Anthracnose (*Glœosporium apocryptum* E. & E.) is known to cause serious injury to the leaves and shoots of the box elder and maple.

Fig. 63.—Oyster mushroom (*Pleurotus sapidus*) on maple, following injury.

Leaf spot (*Rhytisma acerinum* Fr.) is characterized by conspicuous black spots on the leaves of the red and white maples, but is practically harmless.

Nectria cinnabarina (Tode) Fr., a common fungus characterized by small cinnamon-colored pustules occurring on dead wood, follows winterkilling, sun scald, etc. It is especially noticeable on winterkilled twigs of Norway maples.

Oyster mushroom (*Pleurotus sapidus* Fr.) is a large, edible fungus growing in masses on maples that have been injured by borers and other agencies. A mildew (*Uncinula circinata* E. & E.) sometimes infects the leaves of various maples.

Sun scald and frost cracks are not uncommon on maples. The rock maple is one of the most susceptible trees to sun scorch and "bronzing" of foliage induced by excessive transpiration during dry periods. The red maple is susceptible to winter injury of roots, and like the rock maple suffers from drought.

Horse-chestnut (*Æsculus*). — Leaf spot (*Phyllosticta sphæropsoidea* E. & E.) appears in the early summer, and later causes a conspicuous yellow spotting of the foliage. This disease is more or less common every year. The leaves of the horse-chestnut are occasionally affected with mildew (*Uncinula flexuosa* Pk.), and the winterkilled twigs are sometimes attacked by *Nectria cinnabarina*.

Fig. 64. — Horse-chestnut leaf spot (*Phyllosticta*).

Chestnut (*Castanea*). — This is seldom planted as a shade tree, although it is sometimes seen on country roadsides and on lawns. The chestnut blight, which is so serious and so universally distributed at the present time, renders the use of the species as an ornamental tree out of the question. The chestnut is also affected with certain leaf spots, etc.

Sycamore (*Platanus*). — The tree most likely to be severely defoliated by a fungus is the sycamore. The causal organism is *Glœosporium nervisequum* (Fckl.) Sacc., which affects the petioles and veins of the leaves, causing small black areas on these organs. More or less large portions of the leaves turn brown and the leaf finally falls.

The sycamore is unusually susceptible to winterkilling of the twigs, but in spite of this constant defoliation and twig killing it is a very hardy tree.

Poplar (*Populus*). — The principal species in cultivation as shade trees are the Carolina poplar, white poplar, Italian poplar and the Lombardy poplar. The Italian poplar is often severely affected with rust (*Melampsora populina* (Jacq.) Lev.), and a mildew (*Uncinula salicis* DC. Wint.) is frequently observed on the leaves of poplars. Anthracnose (*Marssonia populi*

FIG. 65A.—Italian poplars affected with rust (*Melampsora populina* (Jacq.) Lev.). Unsprayed. (After Maynard.)

FIG. 65B. -- Italian poplars affected with rust (*Melampsora populina* (Jacq.) Lev.). Sprayed with Bordeaux mixture. (After Maynard.)

(Lib.) Sacc.), which attacks the twigs, has been known to cause great injury to many poplars. Poplars are often affected by crown gall and various other diseases.

Oak (*Quercus*). — The oaks are affected by a number of diseases such as *Septoria dryina* Cke., which produces a leaf spot, and by several mildews, *e.g.*, *Phyllactinia suffulta* Reb., *Asterina intricata* E. & M. and *Asterina patelloides* E. & M., *Microsphæra quercina* (S.) Burr. The fungus *Glœosporium nervisequum* (Fckl.) Sacc., which also affects the sycamore, is sometimes found on oaks, affecting the leaf petioles and veins, causing a browning, and, in severe cases, a loss of the foliage. It is most common on the leaves of the shaded branches. *Nectria cinnabarina* (Tode) Fr. also affects the oak. Oak "spangles," little saucer-shaped bodies on the leaves which resemble the work of fungi, is caused by insects.

Hickory (*Carya*). — Two or more leaf spots are found on the hickory, *e.g.*, *Microstroma juglandis* Sacc. and *Phyllosticta caryæ* Pk. Some seasons hickory leaves are quite badly spotted.

Fig. 66. — *Armillaria mellea* on roots of maple.

Butternut (*Juglans*). — Butternuts are affected by the following leaf spots: *Ascochyta juglandis* Bolish, which is more or less common; *Cercospora juglandis* K. & Sw., *Glœosporium juglandis* (Lib.) Mont., *Marssonia juglandis* (Lib.) Sacc. The butternut has suffered greatly from climatic conditions in the past decade.

Tulip Tree (*Liriodendron*). — The leaves of the tulip tree are sometimes badly spotted by insect work which is often accompanied by fungi.

Sweet Gum (*Liquidambar*). — The sweet gum is affected by a leaf spot (*Septoria liquidambaris* Cke. & E.) and is susceptible to winter injury in the north.

Magnolia. — The magnolia is affected by an anthracnose (*Colletotrichum spinaciæ* E. & H.) which ruins the smaller branches and foliage of the tree. Mildew (*Asterina picea* B. & C. and *Asterina comata* B. & Rav.) is also found on the leaves.

Pine (*Pinus*). — The white pine during the past ten years has been affected by a root killing, which has been responsible for the burning of the leaf tips (sun scorch). Various fungi, such as *Septoria parasitica* Hartig, and *Hendersonia foliicola* Berk., have been associated with this trouble, but both are apparently saprophytes. The terminal twigs of the white pine are occasionally affected with *Phoma Harknessii* Sacc., which causes the death of both the leaves and twigs. *Scorias spongiosa* Schw. forms black incrustations on the leaves and twigs of the white pine in the secretions of the woolly aphis. Rust (*Coleosporium pini*) sometimes occurs on the leaves of the pitch pine.

Catalpa. — The catalpa is affected with the leaf spots *Phyllosticta catalpæ* E. & M., *Cercospora catalpæ* Wint., *Macrosporium catalpæ* E. & E., also with mildew (*Microsphæra elevata* Burr. and *Phyllactinia suffulta* Reb.). A blight disease is recorded which causes the leaves to turn black, shrivel and fall. This is said to be caused by insect larvæ. Two wood-destroying fungi, *e.g.*, *Polyporus versicolor* (L.) Fr. and *Polyporus* (Poria) *catalpæ* are found on the catalpa.

Hackberry (*Celtis*). — The hackberry is occasionally planted as a shade tree, and is affected by two mildews (*Uncinula polychæta* B. & C. and *Sphærotheca phytoptophyla* K. & S.) which are associated with a mite (*Phytoptus*) in producing distortion of the leaves. *Phleospora celtidis* E. & M., *Phyllosticta celtidis* E. & K., *Ramularia celtidis* E. & E. and *Septoria gigaspora* E. & E. are responsible for leaf spots.

Beech (*Fagus*). — A mildew (*Microsphæra erineophila* Cke.) is associated with a mite (*Phytoptus*) on the leaves of the beech. The fungus (*Scorias spongiosa*

Schw.) grows in the secretions of woolly aphis, causing a large spongy black mass on the leaves.

HAWTHORNE (*Cratægus*). — The leaves of the English hawthorne are affected often seriously with *Entomosporium thumenii* Cke., which produces spots.

ASH (*Fraxinus*). — The stems and leaves of the ash for the past few years have been troubled with a rust (*Æcidium fraxini* Schw.). The worst cases have been

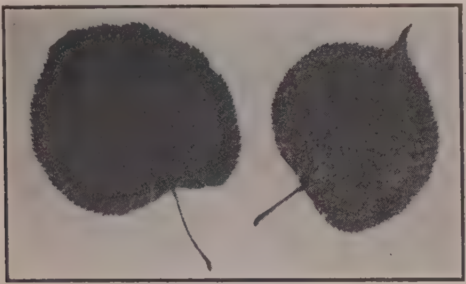

FIG. 67. — Linden leaf spot (*Cercospora*).

found in the vicinity of Cape Cod. The ash is also subject to a leaf spot (*Septoria leucostroma* E. & E.) and mildews (*Phyllactinia suffulta* (Reb.) Sacc. and *Phyllosticta viridis* E. & K.).

LOCUST (*Robinia*). — The locust is unusually susceptible to borers, and when attacked by them often becomes infected with various species of fungi.

LINDEN (*Tilia*). — The leaves of the linden are sometimes badly affected with leaf spots, such as *Cercospora microsora* Sacc., which may be largely controlled by

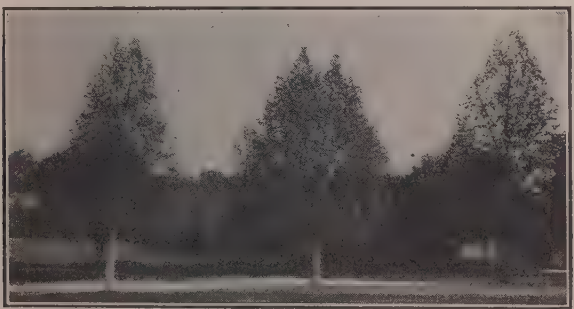

FIG. 68. — Linden tree in center sprayed twice with Bordeaux mixture; others unsprayed.

spraying. The linden in some locations suffers very badly from frost cracks. The American basswood (*Tilia americana*) is subject to a leaf mildew (*Uncinula clintonii* Lev.) and to the leaf spot (*Cercospora tiliæ* Pk.).

ELM (*Ulmus*). — The most common leaf spot found on the elm is *Dothidella ulmi* (Duv.), which is characterized by numerous small black spots on the upper surface of the leaves. Another leaf spot caused by *Phleospora ulmi* Wallr. is characterized by numerous small spots from which gelatinous masses exude in damp weather.

This fungus causes defoliation, and sometimes a great deal of injury results. The mildew (*Uncinula macrospora* Pk.) is found on elms, and *Taphrina ulmi* Johan. is found on *Ulmus montana* and *Ulmus campestris.*

The American elm is very susceptible to drought and winterkilling of roots. Frost cracks are also rather common on the elm, and from these and injury from borers the elm bleeds rather freely.

Sun scald, sun scorch, "bronzing" and various types of winter injury, — such as root killing, death of buds, twigs and branches, frost blisters and frost cracks, — drought effects, "staghead" from various causes, and many other troubles not caused by organisms, are quite commonly found on trees.

There is also a sooty mold that grows in the "honeydew" secreted some years quite abundantly by aphids on various species, which sometimes causes considerable retardation of growth. The honeydew is usually washed off the leaves by rains before it does very much harm, but occasionally, in periods of drought, the concentrated sticky covering remains on the leaves long enough to plasmolyse the cells, causing a mottled appearance of the leaves.

Wood-destroying Fungi.

There are a great number of fungi that may be found on dead wood following various injuries caused by sun scald, insect work, fires, illuminating gas, oil sprays and other agencies. Some of these parasites attack the dead bark and penetrate living tissues of the host, destroying the cell structure, and others are found in the heartwood. By far the largest number of wood-destroying fungi, however, are saprophytic in nature, and find congenial conditions only on dead tissue or that which has become weakened from some cause. These fungi produce different chemical and mechanical effects on the tissues, depending upon the nature of the host and of the attacking organism.

A great many of the fungi that attack wounds are capable of producing cavities, although the heartwood fungi are the chief offenders in this direction. These wood fungi are the most insidious enemies of trees, and quite often no trace of their work is discovered until a great deal of injury has been done. They penetrate the tissues slowly and persistently, and the decay is usually so well hidden from sight that the damage does not appear until the injured tissues are removed with mallet and chisel.

While the wood-destroying fungi are responsible for much injury to trees, fortunately it can be prevented by the antiseptic treatment of wounds; and if the decay has progressed until cavities are formed, these should be thoroughly cleaned and disinfected. The great amount of tree work done during the past few years has demonstrated that the careful removal of infectious material from cavities, followed by thorough antiseptic treatment of the cavities, has been very successful in arresting decay and preventing further injury.

Some of the more common wood fungi are given in the following list. This list is by no means complete as there are innumerable deadwood species belonging to many different genera which it is unnecessary to give. Even some of those listed, *e.g.*, the common birch *Polyporus*, are seldom if ever found except on dead trees.

Most of the wood-destroying fungi develop conspicuous fruiting organs that make them easy to identify. Molds and bacteria are also responsible for hastening decay in trees, often preparing the way for other organisms.

Armillaria mellea Vahl. — A parasite mushroom affecting the roots of maples, oaks and other trees.

Dædalea quercina (L.) Pers. — Occurs in wounds and on dead tissues of the oak and chestnut.

Fomes igniarius (L.) Gillet. — False timber fungus. This is responsible for a heartwood rot common to a large variety of trees, such as maple, oak, hickory, poplar, beech and others.

Fomes rimosus Berk. — Common on the black locust, where it forms large, conspicuous fruiting bodies.

Fomes fomentarius (L.) Fr. — Occurs on the beech and yellow birch, probably as a saprophyte.

Fomes applanatus (Pers.) Wallr. — A deadwood fungus often following injury from fire, etc.

Fomes pinicola Fr. — Causes a decay of conifers.

Hydnum septentrionale Fr. — A large, creamy white growth occurring on wounds of rock maple.

Pleurotus sapidus Fr. — Oyster mushroom (edible). Occurs on maples, elms, etc., injured by borers and on neglected wounds.

Polyporus sulphureus (Bull.) Fr. — Red heart rot. Occurs on various trees, such as oak, maple, locust and conifers. Fruiting bodies consist of a series of sulfur-colored shelves overlapping one another and forming a large, round mass.

FIG. 69. — *Hydnum septentrionale.* (After E. A. White.)

Polyporus betulinus (Bull.) Fr. — Common on dead birches.

Polyporus gilvus Schw. — On deadwood.

Polyporus nigricans. — A wound and heartwood fungus.

Polyporus borealis (Wahl.) Fr. — A wound parasite on species of hemlock.

Polystictus versicolor Fr. — One of the most common fungi, found on a great variety of trees and cut timber. Very destructive as a saprophyte, and as a wound parasite causes injury to catalpa.

Polystictus pergamenus Fr. — Common on trunks of trees following fires.

Schizophyllum commune Fr. — Common on trees injured from various causes.

Stereum frustulosum Fr. — Causes decay to trunks and occasionally found in wounds, etc.

Slime-Flux.

This trouble is common to trees like the elm, maple, yellow birch and apple. It is associated with frost cracks, injury from lightning, splitting of the trunk, defective pruning, etc., and is not uncommonly found in cement-filled cavities. Slime-flux is characterized by the exudation of a slimy, discolored sap from wounds. This exudation of sap is contaminated with various forms of algæ, bacteria and fungi, and occasionally with low forms of animal life, all of which give the sap a sour odor. This fermenting mass is apparently poisonous to vegetation, since it will kill the grass upon which it falls, and also causes injury to the bark and underlying tissues of trees. The whitish appearance given to the bark by the slimy sap often persists for some time after the flow has stopped.

Bleeding wounds often prove injurious to trees, and are very difficult to treat. The bleeding can usually be stopped when it follows defective pruning, as it often does in the elm. Sometimes wooden plugs nicely fitted and driven into the wound firmly will prevent bleeding, and in some cases the tissue may be cauterized by heat. Cement should not be used in cavities that show a tendency to bleed.

Treatment of Fungous Diseases of Trees.

The methods of treating fungous diseases are numerous, but undoubtedly in the future different, as well as simpler, cheaper and more efficient, methods will be used. The use of antiseptics in the treatment of wounds and cavities caused by the worst enemy of trees, — *i.e.*, the wood-destroying fungi — is absolutely essential in controlling this type of diseases.

Little attention has been given to the treatment of the many leaf spot diseases of trees and shrubs, but from what has been already accomplished along these lines we are justified in assuming that these spots can be controlled largely by spraying; for example, trees like the linden, which often becomes badly infected with a leaf spot, are much benefited by spraying. A linden tree,[1] sprayed twice during July and August with Bordeaux mixture, retained its leaves ten days later than trees unsprayed, and the amount of leaf spot was materially less on the sprayed tree. (See Fig. 68.) The leaf spot *Entomosporium* affecting the English hawthorne may be controlled, according to our observation, by spraying with Bordeaux mixture; and there are many other shade-tree leaf spots that yield to this treatment. In many cases, however, it is a question whether the trees are worth the expense and trouble of treatment.

All the rusts are difficult to control, and it is doubtful whether some of them at least are worth treatment. The rust affecting the Italian poplars (*Melampsora*), which at times has been more or less serious, was held in control quite effectively by Prof. S. T. Maynard,[2] who sprayed for

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[1] Mass. (Hatch) Agr. Exp. Sta. Rept. 15, 1905.
[2] Mass. (Hatch) Agr. Exp. Sta. Bul. 25, 1894.

this trouble with Bordeaux mixture many years ago. This rust affects the lower foliage, usually when the dew is most abundant. Infection is sometimes so severe that it destroys the twigs and branches. However, the use of Bordeaux mixture as a spray for ornamental trees is objectionable on account of the discoloration of the foliage, and some prefer the fungus to the unsightly foliage. If possible, some less objectionable spraying material should be employed for ornamental trees and shrubs. Although Bordeaux mixture has proved after many years' trial to be the best all-round summer spray for leaf spots, of late the diluted lime and sulfur solution is being substituted for it with more or less good results. Lime and sulfur applied to dormant trees for the San José scale has proved invaluable as a means of controlling leaf spots, and in some cases it can undoubtedly be used to advantage for certain fungi, such, for example, as the *Glœosporium* infection of the oak and sycamore. It should be applied in late winter before the leaves have begun to appear.

FIG. 70.—Elm tree showing pitted trunk associated with borers. Often observed on trees under uncongenial conditions.

A valuable preventive treatment for fungous infections of trees, in some cases at least, consists in burning the leaves each fall. This is especially valuable with *Rhytisma*, common to maples, for this fungus does not mature its spores while the leaves are on the tree, and burning the contaminated leaves would lessen the chance of infection.

Finally, attention should be given to keeping trees in a healthy condition. Countless examples could be given of the lessened chances of infection possessed by a healthy tree.

WINTER INJURIES.

Injuries resulting from low temperature are common and often cause considerable damage to vegetation. Whether a species is native or introduced it is likely to suffer from winter injury if the proper condition prevails, but plants introduced from regions where the climate is mild are more likely to suffer from the effects of severe cold, although this does not always follow. Moreover, plants grown out of their customary habitats, or under uncongenial conditions, become more susceptible to winter injury. The red maple, for instance, which usually grows in wet places, becomes more susceptible to winter injury when grown in a dry situation, and the same holds true for other swamp species.

Winter injury is often restricted geographically, although during some seasons it may be quite universal. The same type of injury may also be more common, as well as more serious, in one locality than another. The effects of winter injury to trees may also be local, *i.e.*, only the

branches or buds or flowers will be affected; or, again, it may be confined to the roots or other portions of the tree. The apple, pear, quince, peach and plum, various shrubs and vines and small fruits are often injured severely both above and below ground from winterkilling, and much loss results to agriculturists.

FIG. 71.— Same as Fig. 70, with bark removed, showing characteristic sculpturing.

There are several types of injury resulting from low temperature which may be easily distinguished, and which occur almost every year, such as winterkilling of the roots, of the trunks, branches, twigs and buds; also injury to exposed roots; to the cork cambium, resulting in exfoliation of the outer bark; and frost blisters, causing subsequent defoliation.

Winter injuries are not always the result of severe cold, but follow from a combination of factors. Even the temperature of a comparatively mild winter is sufficient to cause much injury to trees and vegetation in general if the preceding summer and fall have been unfavorable for normal plant development. A very dry summer affects the normal growth of vegetation, and if a warm and unusually wet fall follows such a period the plant will go into the winter resting stage under abnormal conditions, and may therefore possess little power of resistance to cold.

Some of the conditions which underlie winterkilling are as follows: —

Severe cold, causing frost to penetrate to a great depth.

Sudden and severe cold following a prolonged warm spell in the fall, in which case the wood tissue is tender and immature.

Conditions which favor a soft growth and immaturity of wood. Various causes may be responsible for this, such as growth in a low, moist soil, too heavy manuring or fertilization, or absence of sufficient sunlight.

General low vitality, caused by insect pests and fungous diseases and lack of moisture in the soil.

Insufficient soil covering, such as lack of organic matter, light mulching and snow covering in winter.

Location in unusually windy and exposed places, etc.

Winter Injuries of Roots.

During the past decade an unusually large amount of injury has occurred to trees through the northeastern portion of the United States as a result of root killing. Innumerable orchards, small fruit plantations and various ornamental plants have suffered, and forest and shade trees form no exception. This injury has been more severe in New York and Ohio than in New England. The trees most severely affected by root killing are the white pine, black oak, white oak, ash, red maple, white maple, elm, butternut, etc.

There are many symptoms characteristic of this root injury which manifest themselves according to the extent and nature of the injury. If the entire root system is killed the tree dies rather quickly. Sometimes an effort will be made on the part of the tree during the spring, especially if a few roots are still alive, to produce foliage, but the tree soon dies. Then, again, a tree will mature its foliage fairly well, but as soon as the

FIG. 72.— Elm slowly dying from defective root system.

soil becomes slightly dry it will die. In such cases the leaves often turn brown and dry up, and remain on the tree in this condition. There are many cases in which the root systems are only slightly affected, when the tree may live for some time and only show a defective top. This slight affection of the root system is particularly common in red maples, which very often recover in a year or two, the only apparent effect being the somewhat smaller leaves found at the tree's crown. In more severe

cases the top of the tree fails to produce foliage, and the characteristic staghead effect is seen. (See Fig. 82.) We have observed elm trees 4 feet in diameter die suddenly from winter injuries to the roots, but more often death from root injury in elms is a rather slow process, the branches dying at the top and usually presenting the characteristic staghead appearance.

Elms and black oaks often show the results of root injury by tufted foliage effects, especially when much of the upper part of the tree is

FIG. 73.—Elm branch with tufted foliage, resulting from winterkilling. A large percentage of the branches on this tree are dead.

dead. The few remaining live branches produce numerous large leaves, — the result of an unbalanced relationship between the root system and the upper portions of the tree. In all cases of root injury those portions of the tree farthest away from the water supply, or, more properly, those which are in less direct communication with the main or principal channels of translocation or mobilization, are affected first. In trees naturally developing single leaders, such as the rock maple, the tops die back first, whereas in the elm, which has several leaders or branches located more or

less alike as regards water supply, each branch is likely to be affected similarly. In evergreen trees possessing a defective root system, sun scorch or burning of the tip of the leaves sometimes follows. This is often serious and may cause a loss of all the foliage, and later the death of the tree (white pine blight).

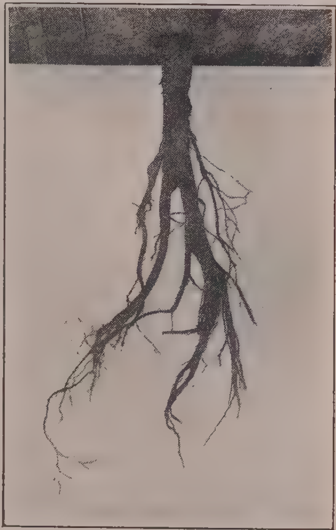

FIG. 74. — Winterkilled root from elm tree. Note lack of fine fibrous roots, which have died.

Many small fruits, grape vines, etc., quite commonly suffer from winterkilling of roots. Plants affected in this way will leave out in the spring, set their fruit and then usually die before it is matured, demonstrating that the maturing and ripening of fruit acts as a severe drain on the water supply of the plant. A fairly large number of shade trees located remotely, or near one another, have died from winterkilling of roots in recent years, necessitating considerable outlay in removing them. Trees located on embankments are very likely to winterkill, that portion of the tree towards the embankment being affected. Roots growing under favorable conditions are less likely to be affected than those growing under poorer conditions, even in case of a single tree. The smaller, younger feeding roots are usually most severely affected, and there is a marked tendency in some species for the roots continually to die back to the trunk when the terminal root system is affected. In these cases numerous new lateral roots are often formed, but as the dying back continues, these are eventually involved. Various fungi soon attack any part of a tree dying from root injury. Later, the bark falls off, but deterioration is not so rapid as in trees killed by other causes.

FIG. 75.—Norway maple affected with *Nectria cinnabarina* following winterkilling of twigs.

While the symptoms of dying back resulting from winterkilling of roots

are not alike in all cases, they are easily distinguished from those of troubles caused by other agents, such as gas poisoning, etc. In the majority of cases trees showing this staghead effect, whether from drought or winterkilling, die gradually, and even when their death is more or less rapid there are few of the symptoms characteristic of gas poisoning. Trees poisoned by gas usually die and disintegrate rapidly; also the diagnostic features to be found in the tissues of trees killed by gas are entirely different.

Winter Injuries above Ground.

There are numerous cases of injury occurring above ground from the effects of winter, such as the dying back of California privet, various fruit trees and vines, our native alders, white birches, the terminal twigs of trees like the horse-chestnut, Norway maple, sycamore, Japanese maple, and a considerable variety of exotic trees and shrubs. Some of the specific types of winter injury to trees will be best treated under the different names by which they are known.

FIG. 76. — Same as Fig. 75, enlarged, showing pustules.

Winter injuries, like other types of injury responsible for the production of dead tissue, are usually followed by various species of fungi, a common form being *Nectria cinnabarina*, characterized by the appearance on the bark of numerous cinnamon-colored pustules, — fruiting bodies of the fungi.

Frost Cracks.

Frost cracks are often seen on many of our shade and fruit trees in winter, and are particularly common to the elm and linden, although occasionally seen on maples. They extend down the trunk for some distance on the sunny side of the tree, and are caused by severe changes in temperature during the winter. Some of our forest trees are also subject to frost cracks; *e.g.*, the striped maple when planted in the open, but never in the dense forest, its native habitat, showing that the trunks of certain trees need to be shaded. Frost cracks open in winter and close more or less in summer, although quite often they never succeed in entirely healing over. In the spring they usually bleed profusely, giving forth a sour, dingy-colored sap called "slime-flux," which shows under the microscope various species of fungi, algæ and yeast.

The opening and closing of frost cracks vary with the temperature, barometer and relative humidity, and so closely is this variation allied with meteorological factors that the weather conditions can be deter-

mined quite accurately. Sometimes frost cracks open 4 or 5 inches or more in winter and close pretty well in summer. They usually extend rather deeply into the wood.

The best way to treat frost cracks is to staple them together. (See Figs. 77 and 78.) Since the cracks open more in cold weather than in warm, this operation should be done in the spring or summer, when the cracks are more or less closed. Staples made from iron three-eighths to five-eighths of an inch in diameter and 4 to 5 inches wide, with prongs of the same length, are best suited to this purpose. The size of the staples depends upon the nature of the frost cracks to be treated. In making up the staples it is a good idea to have the ends of the prongs bent inward a trifle, as they are more likely to hold. The staples are driven into the tree at a distance of from 15 inches to 2 feet apart, as the case requires, and this is best done by first boring holes about the size of the staples. The bark and wood should be removed sufficiently to allow the staples to be driven in flush with the wood, and the exposed tissue should be treated with some antiseptic substance, such as paint or creosote. If it becomes necessary to treat the cavity of the frost crack it should be done in the winter when the crack is open, and such materials as creosote, coal tar and elastic cement or oakum may be employed for this purpose. Disinfecting the wood is a most important treatment, but filling the crack is of secondary importance and is not absolutely necessary. In our experiments the use of staples in large trees has been successful in holding the crack together so that healing of the tree may follow. If the cracks are not held securely together their constant opening and closing, due to the changes of temperature, rupture the healing tissue and prevent the callus from joining. Trees are sometimes so severely injured by frost cracks that they bleed to death, and we have observed maples that had bled to death in a few weeks from this cause. Occasionally the cracks extend from the very top of the tree down to the base, when there is small chance of the tree surviving.

FIG. 77.—Effective method of treating frost cracks by iron staples. (See Fig. 78.)

FIG. 78.—Section of tree showing frost cracks and iron staple method of preventing opening, thus facilitating healing.

Winterkilling of Cork Cambium.

As already stated, the effects of low temperature on a tree may be entirely local; *i.e.*, it may affect some particular organ or some one portion

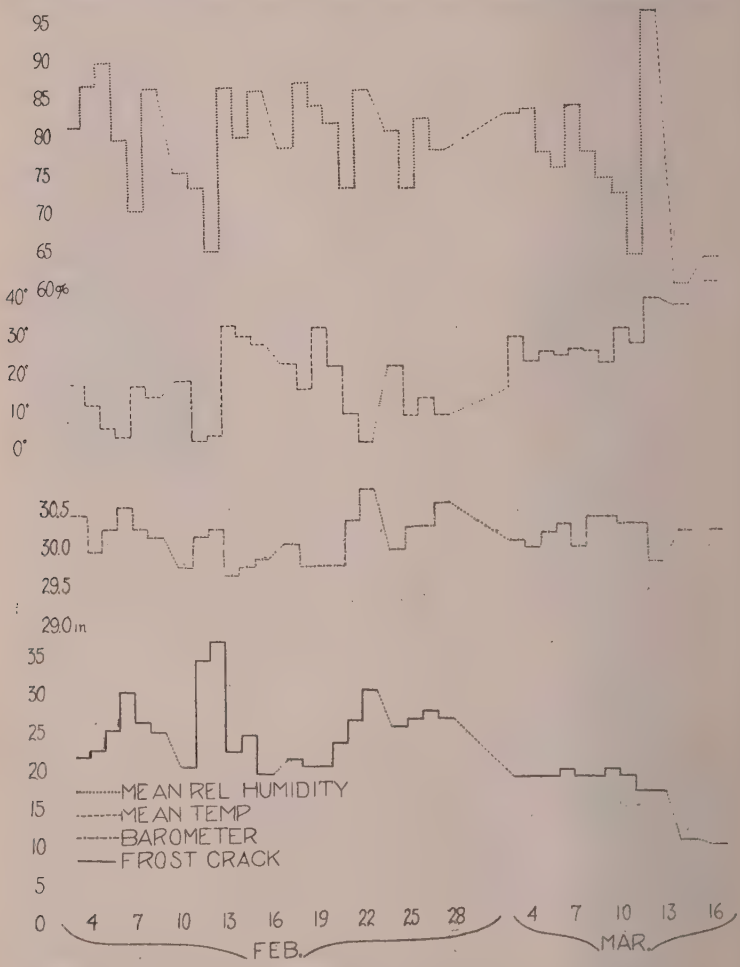

FIG. 79.—Showing curve of opening and closing of frost cracks in elm trees. The lower curve represents the variations in the opening and closing the others represent the mean relative humidity, mean temperature and barometer in the order named.

of the tree only. Following one of our extremely severe winters a few years ago, elms and some sycamores were found suddenly discarding their outer bark, — a rather unusual phenomenon. This loss of the outer

bark was brought about by winter injury to the cork cambium, a vital layer located between the outer and the inner bark. It did not injure the tree in the least, since the inner bark and the cambium layer underneath remained unaffected. As the collapsed cells of the cork cambium decomposed, the outer bark became loosened from the tree and fell off in a year or two, covering everything it happened to fall upon with a peculiar reddish powder. A microscopic examination of this powder showed it to consist of disintegrated cork tissue, or lamellæ. This injury to cork cambium from low temperature, although observed here and there, was not common. In one city in New York, however, 50 trees were affected, but in only one or two instances did injury extend to the wood and involve the cambium layer. One large sycamore tree 4 feet in diameter, which we observed, lost all of its outer bark, but is in good condition at the present time. The large section of bark, composed of many annual layers of cork, fell off in a comparatively short time, giving to the trunk an unusual whitish appearance. Occasionally there may be found in our State elm trees in which the cork cambium has been affected by winter temperature, resulting in a subsequent loss of the outer bark. But the exfoliation of small portions of the outer bark of elm trees is not uncommon, and should cause no apprehension.

FIG. 80. — Elm tree which has lost its outer bark, resulting from winter injury to cork cambium.

Sun Scald.

Sun scald is a type of injury affecting unripened wood. It is quite commonly met with on rock maples and orchard trees and on some of our wild shrubs. Shade-loving trees are particularly susceptible to sun scald, as may be observed in any forest clearing. For instance, the moose maple, a shade plant, seldom scalds in its native habitat, but when timber is removed and the sun allowed to enter, it is affected. This tree is undoubtedly the most susceptible of any to sun scald.

On the apple sun scald is often associated with canker (*Sphæropsis*). White pines also, when thinned too freely, will sun scald severely on the trunk. Many shade trees in our State show injury from this cause, the trouble being more common in some localities than in others. In one section of a city in the eastern part of the State more than 60 per cent. of the maples were found to be suffering from sun scald. The scars, which were confined to the trunk, were invariably on the sunny side of the tree,

being more commonly on the southwestern side, where the maximum temperature was usually found.

Sun scald does not usually involve the whole trunk of large trees, but in many cases, particularly small maples, the whole tree will suffer. A few years ago, in a comparatively short distance on one street, 16 maples had died from sun scald, and at one time our wild cornel (*Cornus circinata*) suffered severely from this trouble, many of them never recovering.

Quite often young rock maples will show only small spots affected by sun scald, proving that the injury may be only local, as in the case of the apple, on which tree sun scald often takes the form of collar rot. Sun scald on apples is often confined to the shaded branches, and sometimes occurs on severely pruned or dehorned trees.

FIG. 81. — Fungi following attacks of borers on rock maples, resulting from extreme drought.

In some cases sun scald will be found on tree roots and root buttresses exposed by regrading. Instances of this class of injury have been noted, particularly in the case of hickories. Any regrading necessitating the exposure of roots should be done in the spring rather than in the fall. Piling soil too high around the base of young apple trees produces injury, and frequently results in girdling the trunk and the death of the tree.

Most cases of sun scald are followed by an outbreak of *Nectria cinnabarina*, as is often the case with winter-killing. The treatment of sun-scalded areas should consist in scraping the wood, after removing the bark, and treating with some such antiseptic or preservative material as creosote and coal tar, or thick paint.

Drought.

The unprecedently long period of drought of the past five or six years has been an unusually severe drain on vegetation in general. While the rainfall records for this period show quite a marked falling off from normal, it should be borne in mind that rainfall is only one factor in producing drought, and the amount of rainfall seldom gives a correct idea of the severity of drought. So far as crops are concerned, the amount of water contained in the soil is a most essential factor. This is determined not only by rainfall but by the amount of water withdrawn from the soil by surface evaporation and the transpiration of plants. Enormous quantities of water are removed from the soil by these processes, which are much influenced by sunshine and wind. The amount of water transpired by the foliage of trees varies greatly from day to day. When the meteorological conditions are favorable for this function, as they usually are during hot, dry seasons, enormous quantities of water are taken from the soil into the air; consequently the soil may contain much less water than rainfall records would indicate.

One of the common effects of drought on trees is the premature yellowing and falling of the leaves. Quite often, however, as in the case of the elm, the leaves fall off in large quantities without turning yellow, and the not unusual habit of this tree of shedding its terminal branches may be associated with drought. During dry periods the leaves of rock maples often sun scorch, particularly when strong winds are blowing; and what is known as bronzing of the foliage is associated with a lack of water.

Drought in summer interferes with the development of the tissue, thereby affecting the growth of trees. In times of unusual rainfall a renewed activity often takes place in the fall, when many shrubs will begin to blossom again and throw out new leaves. The result, especially in very cold winters, is a susceptibility to winterkilling on the part of the tissue.

FIG. 82. — Showing maple with staghead effect.

Drought is responsible for many pathological conditions in trees. Many of them, such as the rock maple, the European cut-leaf birch, the white ash and others, become weakened and therefore more susceptible to attacks from borers and in some instances to scale insects, as a result of which many trees die. When plants enter the winter resting period after a drought in the fall they are very likely to become victims of winter-killing.

Severe drought affects the roots of trees, which are unable to thrive with so little soil moisture for any length of time, especially when the soil is dry as powder to a considerable depth. During the past three years the root systems of numerous maples, elms and other trees have been severely affected by drought, as shown by the cases of staghead and the unusually large number of trees that have died during this period. Trees affected by severe drought sometimes die suddenly, but more often they linger in a dying condition for a few years. The wood of trees like the elm, when dying from drought, is invariably quite brittle, owing to the fact that the decreased water supply from the roots causes a transformation of the sapwood into hard wood.

Shade trees growing in dry situations may be greatly helped over periods

of drought by cultivating around them, by supplying water, or by turning under the sod and applying manure heavily. Planting a crop around the tree is also beneficial, but when this cannot be done conveniently, water may be supplied to the roots through numerous holes 1 or 2 feet apart and 12 or 15 inches deep, driven in the soil by means of an iron bar. In applying the water it is important that the feeding roots be reached, and perhaps a small amount of plant food may be added at the same time. Sometimes wells are installed near the feeding roots of trees; and tile aqueducts can be placed under trees at the time of planting, through which water can be supplied to the roots of the tree. This latter method would prove valuable in periods of drought for trees like the European birch and others which are greatly weakened by any deficiency in the water supply.

FIG. 83. — Red maple, alive with inferior foliage at the top.

Sun Scorch and Bronzing of Leaves.

Sun scorch is a physiological trouble characterized by the wilting and burning of the foliage of several species of trees during the spring and summer. Sun-scorched leaves often present only a few dead, brownish areas located on the margin of the leaves, or comprising more or less large areas of dead tissues between the leaf veins. When a strong wind is blowing the dead areas often disappear and the leaves present a lacerated appearance.

Sun scorch is caused by severe warm winds when the soil moisture is low. It is more common in the spring and early summer, when transpiration is at its maximum, the leaves transpiring more water than the roots can obtain from the soil. As a result they become wilted, and those parts of the leaves which fail to recover from the wilt die. Identical troubles affect agricultural crops, ornamental shrubs, etc., although known by different names. Tipburn of potatoes and onions, topburn of lettuce and

the so-called winterkilling of conifers and rhododendrons in the spring are in reality sun scorch.

The rock maple is most commonly affected by sun scorch, although other trees suffer to a certain extent. There is seldom a season that this species does not sun scorch, and during the summer of 1913, 30 per cent. of the trees in some localities were sun scorched so badly that the foliage presented a decided reddish brown appearance.

Fig. 84. — Elm tree showing staghead from defective root system. Note dead, stubby branches at the top.

As already stated, strong winds are one of the prime causes of sun scorch. A few years ago in May there was a wind from the northwest which blew at the rate of 71 miles per hour, and as a result many thousands of rock maples sun scorched throughout the State. Burning in all cases was confined to the northwest side of the tree. The particular winds which cause sun scorch may easily be ascertained, for that part of the tree exposed to the prevailing winds is always the one affected.

Some trees are subject to sun scorch each year. Light, porous soils having little water-retaining capacity are responsible for a great deal of

this trouble, as shown by the fact that the white cedar, arbor vitæ, etc., accustomed to wet situations, are quite susceptible to sun scorch when grown out of their natural habitat. There is also reason to believe that in some cases a peculiar chemical condition of the soil or some variation in the root absorptive capacity, which limits absorption, is at the root of the trouble.

We have been observing for a long time maple trees which sun scorch badly each year. During especially severe droughts every leaf is affected, while trees located near by are not in the least injured. The leaves of trees suffering from sun scorch do not usually fall off, but remain alive, although discolored. It is impossible for them to perform their full functions, but little injury results to the tree.

Rhododendrons, arbor vitæs and other conifers often burn in the spring before the frost is out of the ground, when strong, warm, dry winds occur. When they are mulched the frost remains in the ground longer than it otherwise would, and the winds cause more transpiration of water than the roots can supply. Many rhododendrons meet their fate in this way, their death usually being attributed to winterkilling. This can be prevented by removing the mulching early in the spring and allowing the sun to thaw out the frost.

"Bronzing" of foliage is merely another form of sun scorch common in very dry, hot periods. It is not caused by wind, and there is no laceration of the foliage. Examination shows that the cells near the veins and veinlets of the leaves are alive, but those farthest away are dead. This bronzing is caused by a lack of water supply to the cells of the leaves located most remotely from the veins or source of water supply. Like sun scorch, it is associated with excessive transpiration and diminished root absorption. The leaves become a reddish brown or bronze color, the dead tissue giving them this peculiar hue. It is most commonly met with on the rock maple, though other trees sometimes show the same trouble.

Mechanical Injuries.

Although trees possess quite a remarkable power of growth, by means of which they are able under certain conditions to overcome apparently insurmountable obstacles, they do not always make use of this power. When roots and other organs are restricted in some way in their growth, they often lift objects weighing many tons, but when there is opportunity for active tissues to flow around the object, as it were, this more practical and easier method is used. Every type of injury to a tree acts as a stimulus, hence there usually follows an accelerated growth of the tissues around the wounds, which often produces disfigurement.

Under the heading "mechanical injuries" may be described many injuries arising from various causes. The injuries due to wires have been treated in Bulletin No. 156. In cities and towns perhaps one of the most common injuries to be seen on roadside trees is that caused by horses' teeth. Trees located between the sidewalk and the road are

especially liable to be gnawed by horses, but the many good types of tree guards to be had make most of this inexcusable. There are statutes which cover such cases of injury, but it is always better for the tree warden or city forester to prevent injury by the use of a tree guard than by resort to courts. Very often trees are injured by being so close to the roadbed that heavy teams come in contact with them and cause abrasions. This is common in large cities where there is a great deal of heavy traffic. Runaways are also responsible for occasional injury, and for all these reasons the ideal location for a street tree is that known as a "tree belt." Many of the modern streets are now provided with tree belts 4 to 10 feet wide or more, situated between the sidewalk and the road. When such space is available it is possible to plant trees some distance from the curbing, preventing injuries from heavy teams and horses' teeth. The most frequent offenders are grocerymen and marketmen. It is their common custom everywhere to leave their horses unhitched in front of a house, within easy reach of any trees located near the roadside. Tree-belt planting prevents this difficulty. If tree belts are not available, it is advisable to plant the trees inside the sidewalk near the highway line, and since on every well-kept avenue there are fertilized lawns, a tree in such a location is under desirable conditions for healthy growth.

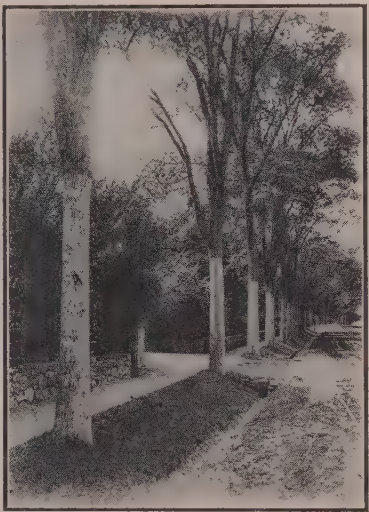

FIG. 85. — Elm trees with bark scraped, illustrating a hideous and useless practice.

FIG. 86. — Obliteration of signboard on tree, resulting from stimulated callus growth.

Placing signs on trees is another objectionable feature. Since the signs cannot accommodate themselves to the tree's growth, the bark grows over them, causing ugly scars. The same objection holds true of the fastening of other objects, particularly wire fences, to trees.

Some injury to trees is occasionally caused by spurs. Trees have sometimes been severely injured in this way, and as a rule all climbing of

trees should be done without the use of spurs. Most of our intelligent and thoughtful foresters and tree wardens never allow them to be used.

Ice is responsible for much disfiguration of trees which cannot easily be prevented. It affects more particularly such soft-wooded trees as the white maple, and greatly mutilates them by breaking down their limbs.

Posting advertisements on trees on country roadsides is another objectionable practice, but this is prohibited by law in Massachusetts. (See page 263.) A great many roots are injured and destroyed by the

FIG. 87.—Trunk of an elm tree, showing old trunk and new formation of roots.

laying of gutters and curbs, sewers, water and gas pipes, telephone conduits and catch-basins, but at present this seems to be unavoidable.

Earth Fillings around Trees.

The remodeling and regrading of streets, lawns, etc., often necessitate filling in around trees. These earth fillings are usually fatal to trees, no doubt owing as often to the effects of the earth on the bark as to the lack of air to the roots from the deep covering of the soil. We have seen trees growing on a bank with one side of the root system and part of the trunk covered with soil. Those parts covered with soil gradually died, and finally the whole tree died. The maximum depth of soil around the trunk was not more than 8 inches, but the roots were covered for 18 to 20 inches. The soil used for refilling was of a fine texture, — undoubtedly

more injurious than a loose-textured soil would have been. In this case the death of the trees was caused by too close contact of the soil with the bark. When a stone wall is first built around the tree at sufficient distance to allow for future growth, to keep the soil away from the trunk, trees filled in to a height of 5 or 6 feet have been known to survive for many years.

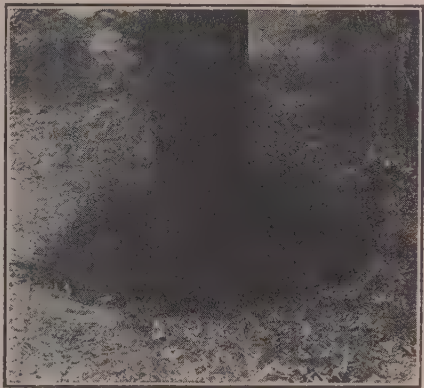

FIG. 88. — Red maple injured by earth filling 1 foot deep.

Some trees are undoubtedly more easily injured by earth fillings than others, but building a wall around them to keep the dirt from the trunk, or even the use of cobble stones, brick or coarse gravel close to the trunk, tends to prevent injury. Banking soil for even a few inches around young trees sometimes causes injury.

There are many instances where trees which have been buried partly up the trunk threw out a new root system nearer the surface of the soil. The tree shown in Fig. 87 had been filled in with soil to a depth of 4 feet thirty-five years ago, and in removing the tree it was found that the old stump and roots were all decayed, but the new surface roots had proved sufficient to support the tree.

FIG. 89. — Wall built around the base of a tree to prevent injury from earth filling. (See Fig. 88.)

Bleeding of Trees.

A great many trees suffer from bleeding from different types of injury such as borers, lightning strokes, frost cracks, splitting of the trunk, and occasionally linemen's spurs. Often trees filled with cement bleed; and the exudation, containing magnesium compounds derived from the cement together with various microörganisms which thrive in the exuded sap, gives an unsightly appearance to the bark. Bleeding to excess is very injurious. Sometimes the death of trees from this cause is sudden, and in other cases the tree will linger, gradually dying back at the top, and eventually dying. The exuded sap, or "slime-flux," sometimes proves detrimental to the living tissue, as shown by the presence of saprophytic fungi.

Elm trees often show a white streak on the bark, caused by some injury resulting in bleeding, and maples are also quite often affected, sometimes going into a slow decline, followed by death from bleeding alone. These injuries are a difficult class to treat, and at present no satisfactory method is known.

FIG 90. — Bleeding elm. The white streak on the limb and trunk shows the slime-flux.

Injurious Chemical Substance.

Kerosene Oil.

Many different oils have been used for spraying insect pests, some of which have proved reliable and others injurious. Kerosene oil can be used on some plants under certain conditions without causing injury, while in other cases it will kill them. A few years ago there was placed on the market a spraying device for the mechanical mixing of kerosene and water in different proportions, but when these materials are mixed mechanically they separate on the tree, and they have been responsible for the death of many trees. The oil soaks into the bark and often reaches the cambium and sapwood, destroying the tissue; and we have seen quite a few shade trees killed by spraying with kerosene and water to exterminate woolly aphis. In some cases every part of the tree touched by the kerosene was injured, while in others the injury was only local, a more commonly noticed condition on thick bark trees, while the former case was invariably restricted to trees with thin bark. The bark of trees killed by the use of kerosene presents a different appearance and develops usually a different type of fungous flora from the bark of trees dying from other causes; besides, traces of the oil, which remain on the tree for a long time, can be detected by the sense of smell. A fair diagnosis of this type of injury may be made from specimens of the bark, but when there are comparatively slight local injuries it is best to examine the tree *in situ*. Even slight traces of oil may be detected by removing small portions of the outer bark on the sunny side of the tree, the sun's heat causing a slight volatilization and perceptible odor.

Gas Oil.

Gas oil, a heavy oil used in the manufacture of water gas, is very injurious to trees when used as a spray. A few years ago several hundred shade trees were severely injured in one of our eastern cities by spraying

the trunks with this oil to kill clusters of gypsy moth eggs, it being used without any knowledge of its adaptability to this purpose. (Fig. 91.) The oil quickly soaked into the bark, cortical tissue and cambium, and in some cases extended into the sapwood for one-half to three-fourths of an inch. This injury occurred even on trees with fairly thick bark, killing all the living tissue wherever the oil was applied. While in some instances the trees did not show extensive injury, in others the trunks were 50 to 90 per cent. girdled, and many of the trees died from complete girdling. The most striking feature of this case was the ability of the trees to produce perfect foliage even after serious injury had taken place. One tree was examined whose trunk was girdled for a height of 15 to 20 feet, but this tree persisted in producing foliage for two years after the bark had fallen off. An explanation of this remarkable case consists in the fact that the heavy oil soaking into the sapwood prevented it from checking or cracking, therefore the supply of water from the roots was uninterrupted. The trees treated were elms, different species of maples, which are especially susceptible to injury, and others. The presence of oil in the sapwood in the cases cited above was of the greatest aid in preventing cracking and in helping to maintain the transpiration current and normal foliage, and this bears out the recommendation that tree wounds, very soon after they are formed, should be painted or treated in some way to prevent cracking. It is sometimes necessary to scrape the wound before applying the paint.

FIG. 91.—Effects of spraying heavy oil on trees. The oil penetrated the bark and killed the tissue.

FIG. 92.—Maple injured by burning leaves near the base of the tree.

Paint.

Ordinary house paint, although a crude enough treatment, has sometimes been used by ignorant persons on smooth bark trees, with, of course, resultant injury.

Miscible Oils.

Occasionally commercial oils used for spraying fruit trees for the San José scale cause local injury, and some shade trees have been known to be affected by their use. This is especially true of maples, and it is never safe to use oils of any sort on many smooth bark trees.

Road Oil.

Oils and other materials to keep down the dust in roadbeds are now much in use, and we have observed some injury from this source when the trees were located close to the highway and the buttresses of the roots were exposed. The roots are much more susceptible to injury from various causes than are the trunks, as they are not so well protected by bark, and when oil sprinkled on a roadbed touches some of the exposed roots it kills the tissue. Particles of dust from oiled roads which sometimes alight on the foliage of trees are said to cause injury, but this type of injury is rare with us. Whether the oil ever penetrates deeply enough into the roadbeds to reach the root systems of trees is not as yet known, but if it does it may cause serious injury. Neither are there specific cases of injury to the roots of trees by the dripping of oil and gasoline from automobiles, although if this leakage were sufficient it might reach the roots and cause injury. Not long ago, however, our attention was called to a tree supposed to have been killed by gasoline leakage from a near-by garage.

Creosote.

This material is used extensively on trees for disinfecting cavities, and, mixed with lampblack, for painting gypsy moth egg clusters. It does not appear to penetrate to any great extent when combined with lampblack. We have examined a great many trees to discover injuries from its use with no success, except in the case of linden roots, which had been exposed by regrading, where the underlying tissue was injured. But such instances are rare and the injury purely local in character.

In one case a combination of creosote and naphtha applied to a large number of trees for the destruction of gypsy moth caterpillars appeared to soak into the outer bark, apparently killing the cork cambium, which later resulted in a disintegration of the tissue. Whether these substances did further injury to the tree we were not able to learn.

Coal Tar.

Coal tar is much used for painting wounds and scars caused by pruning, and sometimes injures delicate tissue when first applied. The injury, however, is not serious, as shown by the fact that various saprophytic

fungi will develop where the coal tar has been put on. After coal tar has been on for some time it is evidently not injurious, even to delicate tissue.

Salt.

Salt used on sidewalks, in gutters and on trolley lines in winter has been known to cause injury to the root systems of trees. In one instance we noted injury to several small maples growing near a sidewalk and gutter which had been treated heavily with salt. In some cases where salt had been used extensively on trolley tracks, injury to trees was observed. It should not be used near valuable trees.

Other Injurious Factors.

Arsenate of soda, potassium cyanide and other chemicals are extremely poisonous to trees, and when placed in holes bored in the tree the two first named will soon cause death. Since arsenate of soda is often used as a weed killer, it is recommended that care be taken in applying it around the feeding roots of trees.

A quite common opinion among linemen is to the effect that copper spikes driven into trees will kill them, but a small maple so treated by us a few years ago showed no abnormal symptoms.

The foliage of different trees is often injured by spraying with various fungicides and insecticides. It is well known that plum and peach foliage is quite susceptible to this type of injury, and even the leaves of maples and other trees may be injured by arsenate of lead. The extent of the injury depends not only on the nature of the spraying solution or mixture used, but also on the condition of the foliage sprayed. We have observed injury to maples from the use of 12 pounds of arsenate of lead to 100 gallons of water; and Paris green, owing to its present-day uncertain composition, often burns foliage.

Burning insect nests with torches, although a common practice, is a bad one, and invariably causes injury. Serious harm often results from burning leaves and grass around trees, and the roots of forest trees, which are often close to the ground, are sometimes injured by burning the underbrush.

In conclusion it may be said that in any treatment of trees one should always have before him some definite object; he should leave strictly alone the numerous irrational methods constantly being advocated, or apply to them first the measuring stick of common sense.

Banding Substances.

During the past fifteen years a large number of banding substances have been placed on the market, all of which with one or two exceptions have proved injurious to trees. These substances usually contain some oil which affects vegetation injuriously, in some cases even when applied over tarred paper. The injury caused by banding substances varies

greatly, the tree often being completely girdled, and again only a local effect is produced; *i.e.*, portions of the tissue here and there will be affected by the material. This results in relieving the tension of the tissue at places, and an abnormal growth of the tissue follows.

"Tanglefoot" appears to be the only substance that does not cause injury when applied directly to the bark, *i.e.*, when tarred or other heavy paper is not used. Many laboratory samples of substances resembling "Tanglefoot" have been made up, but in only one instance have any of these materials resembled "Tanglefoot" in virtually all its properties; at least, among those which have come to our notice. While the injuries from banding substances have been quite pronounced, practically all of the substances causing injury have now been discarded.

An examination made by the writer of many trees treated with the so-called "Tanglefoot" has revealed only one case of girdling, and even in this case we were not able to obtain any clue to the manufacturer of the particular material causing the injury. This substance, although resembling "Tanglefoot," may have been one of its many imitations some of which are known to cause injury. The only other case of injury from "Tanglefoot" was where it had been applied to the trunk at the same place for a number of years. The oil seemed to penetrate the outer bark to some extent, affecting the texture of the bark; but this injury is not serious, so far as we have observed, and can be prevented by changing the location of the band occasionally. We have never noticed any injury from the use of "Tanglefoot" to the cortical tissue or cambium located underneath the bark. Our previous experiments show that the most delicate tissue was not injured when it was applied to various plants. But injury was noticed to smooth bark trees when other banding substances were applied, even on tarred paper. Tarred paper alone is capable of injuring the bark of some trees, and the injury mentioned above may have been caused in this way in some cases.

Effects of Illuminating Gas on Trees.

A much larger number of trees suffer from the effects of escaping illuminating gas in the soil than formerly. The increased death rate from this cause may be accounted for by the fact that gas is now more extensively used, and the larger pipes and different types of connections employed, together with the changes in the methods of laying and calking the joints, also play their part; at least there is much less leakage from small pipes having thread joint connections, which have been in the ground for many years, than from larger pipes calked with oakum and cement or lead. Electric cars, steam rollers, motor trucks and other heavy traffic on highways are often responsible for defective joints and the consequent leakage of gas, especially in newly installed lines. Also, the continual undermining of gas conduits made necessary by the construction of sewer and water lines, as well as the effects of frost in very cold winters,

cause leakage; and, finally, the wires, steel rails, etc., carrying electricity are a constant source of danger to gas pipes, as is occasionally proved by cases of electrolysis.

A large amount of the gas manufactured is unaccounted for, often averaging 10 per cent. This loss may be accounted for in part by discrepancies in meter readings, etc., and should not be laid wholly to leakage, and a small percentage of unaccounted-for gas is of slight importance. It should be stated in justice to many of the large gas producers that every effort is usually made to prevent leakage and injury to trees. Some of the most progressive manufacturers spare no expense in constructing and maintaining their lines, although it must be confessed that there is great need for improvement in methods of conveying this dangerous substance. The larger pipes, which are more difficult to keep calked securely, furnish better facilities to patrons; nevertheless the danger from leakage is greater. There are numerous connections in gas mains from which the leakage is slight, perhaps only a few cubic feet a day, while in others it is very great. Even small leaks, if neglected, will injure trees in the course of time, owing to the gradual saturation of the soil with gas.

FIG. 93.—Maple tree dying from the effects of illuminating gas, with characteristic fungous (*Polystictus*) growth.

There are several kinds of gas used for lighting and heating, *i.e.*, water gas, coal gas, gasoline gas, acetylene gas and others, but their effects on the plant are quite similar, and they are all very poisonous to vegetation. The poisonous properties are largely confined to the numerous products absorbed in small quantities by the soil moisture, taken up by the roots and translocated through the tissue. The reactions to the substances are not quite the same in different locations nor in different species of trees. Trees poisoned by illuminating gas usually show some characteristic post-mortem symptoms, but the problem of diagnosis is greatly complicated by the fact that many of these symptoms may be found in trees dying from other causes. More or less rapid deterioration and increased brittleness of the wood are quite characteristic symptoms, however.

In summer, the first effects of gas poisoning may be seen in the foliage. The leaves often turn yellow and drop off, while in other cases the leaves will fall when still green, and, again, the leaves will turn a reddish brown and die without falling. The upper part of the tree, being far from the source of water supply, usually shows the effects of defoliation first. These various symptoms occur before there is any evidence of abnormal tissue above ground. But after the water in the soil containing the poisonous

gas principles has passed up through the roots and stems, the sapwood, cambium and bark become abnormal. The first symptoms take the form of a characteristic dryness of the cambium and other tissues outside the wood, this being the first indication of the approaching death of the tissues. Later, these tissues — cambium, phloëm and cortex — turn brown, and disintegration follows. The roots, which first absorb the poison, are naturally the first to become abnormal, but later, as absorption and translocation proceed, the poisonous constituents may be detected in the wood at the base of the tree. It not infrequently happens that the tissue here is dead, while that in the trunk a few feet above is alive, but this condition does not endure, the whole tree sooner or later becoming affected. When the underlying tissues die the tissue tensions are destroyed and the bark changes color, gradually growing darker, and its physical properties become greatly changed. Soon various species of fungi, such as *Polystictus*, *Schizophyllum* and others, find a foothold on the bark, and borers and other insects attack the dead tissue. Even bacteria and molds, like *Penicillium*, become active and hasten the process of disintegration. The smaller twigs become dry and brittle, and the ends often break off; the upper limbs usually lose their bark first, but eventually the larger limbs present the same appearance. Disintegration may take place so rapidly that in one and a half to three years the bark disappears and most of the larger branches break off, and soon nothing but a portion of the trunk and a few stubs remains.

FIG. 94. — Effects of illuminating gas on elm tree one and one-half years after leakage occurred.

It must be understood that many of the symptoms mentioned above may also be found in trees dying from other causes and do not necessarily constitute reliable guides to the detection of gas injury. The tissue furnishes the best symptoms for diagnosis, and the writer, who has for the past twenty years been examining hundreds of trees killed by gas, from the first found it necessary to make a thorough examination of the tissue to warrant any degree of accuracy in the diagnosis. He has

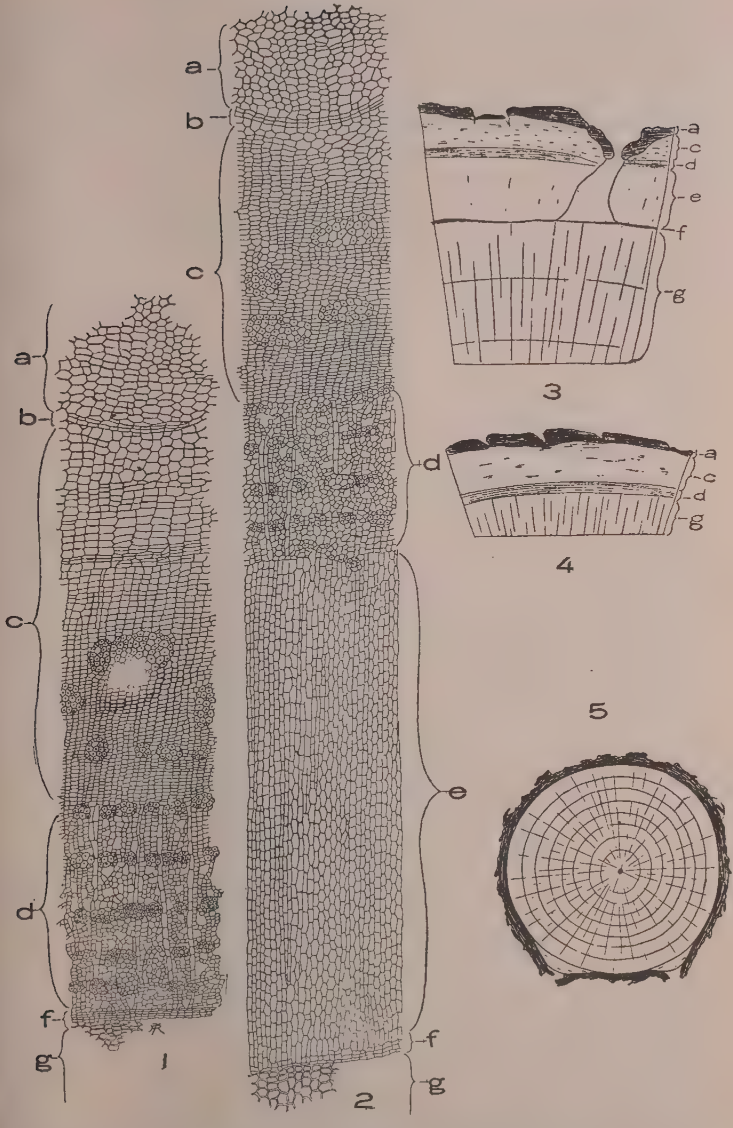

FIG. 95.—Showing cross-section of Carolina poplar (*Populus deltoides* Marsh). 1, Cross-section of normal stem, enlarged; 2, same, showing abnormal growth; 3, naked-eye view of same; 4, section of a normal stem; 5, cross-section of trunk of tree showing the splitting of the bark; *a*, bark; *b*, cork cambium; *c*, cortex; *d*, phloëm; *e*, abnormal parenchyma; *f*, cambium; *g*, wood or xylem.

also taken exhaustive notes on every symptom shown by trees dying from various causes, and from these notes may be had many interesting data on the relative importance of various symptoms. In diagnosing gas injury one must learn to detect either by chemical means or from direct observations and experience the presence of the poisonous constituents of illuminating gas which are absorbed by the roots and circulate to a certain extent through the tissues of the wood.

As already intimated, no two species of trees suffering from gas poisoning present precisely the same symptoms, and there is much difference existing in the same species, the location, season of the year and other factors having an important modifying effect. Trees, for example, when examined in the fall, will show slightly different symptoms from those examined in the spring. This is also true of trees poisoned by gas from different manufacturing plants, which varies considerably. The variation in the chemical constituents of the soil here and there may to a certain extent account for the variations in the reaction of gas on the tissues, but this factor is probably not very important, since these variations in the soil are likely to be found even in a single town supplied with gas from one source, and as a rule the symptoms of trees injured by gas from a single manufacturing plant are alike. Tables giving the results of gas analysis from various corporations, however, show that there is considerable difference in the composition of gas, and that gas from a single manufactory is likely to vary slightly from day to day, not only in the percentages of carbon monoxide and hydrogen, but in the other products.

The odor and color of the tissue should first be examined carefully when diagnosing a gas-injured tree, although it is possible by the use of chemicals to obtain reactions and to detect certain products in the tissue. There are different odors associated with the wood of trees which die from various causes, and it is therefore necessary to become familiar with these before relying too closely on this factor. For instance, molds and other micro-organisms found in the sap of trees dying from various causes often cause decomposition with resultant odors. But there will always be found in trees killed by gas peculiar characteristic odors difficult to describe, and more easily recognized, at least above the ground, after a tree has been dead for a few weeks or months. The odor is more prominent in moist than in dry trees, and can be detected in the tissues of the bark as well as of the wood. Sometimes this odoriferous wood is found deep in the sapwood, and can be recognized in the stumps of trees freshly cut, but in old stumps, where decay has set in, it is not always discernible. In such cases some part of the root system, if dug up, is likely to give a characteristic odor, except when the wood has become too dry and a more or less advanced stage of decay has set in. Even the rate of disintegration and the nature of the decay are often characteristic, and are of some value in diagnosis.

It should be remembered that the odors of different species of trees, even when in normal condition, differ greatly; *i.e.*, the natural odor of the

maple is quite different from that of the elm, horse-chestnut or red oak, and their products of decomposition also differ. The accurate diagnosis of trees killed by illuminating gas is highly specialized and technical. Nevertheless the characteristic odors given to the tissue by illuminating gas can be discerned quite accurately by one thoroughly familiar with them. Sometimes these odors are found in all of the tissues of the trunk, but more often they are confined to some special part of the tree or root. They are far more pronounced at the base of the tree, and rarely found in the top. Carolina poplars and willows often display peculiar reactions to gas poisoning. The bark splits open and large masses of soft, parenchymous tissue are formed directly from the cambium layer. When the tree dies this parenchymous[1] tissue decomposes into a mucilaginous mass. (See Fig. 95.) Some species appear to be less often affected by gas poisoning than others. It is a question whether there is much difference in susceptibility, however, as regards species. Trees like the elm and maple, with a large spread of the roots, naturally become poisoned if located near gas leaks, and some trees are adapted to more strenuous conditions and possess a greater capacity for regeneration than others, although they may be as susceptible to poisoning as trees of other species. Coniferous trees possess the greatest resistance to gas poisoning of any species, and in many instances they have been observed surviving in an apparently healthy condition when located dangerously near broken mains, while deciduous trees located much farther away would always succumb. In some cases where conifers have actually been poisoned to quite an extent they have completely recovered. This response may in part be explained by the protection furnished by the coating of micorhiza on the roots of conifers.

We know of no remedies which can be applied to trees already poisoned by gas, since the injury occurs below the surface of the ground, and the effects are seldom noticeable until the poisoning is more or less pronounced. If the leakage of gas could be discovered quickly and the leak repaired, the effects on the roots might be prevented, but this is rarely the case. Illuminating gas in small quantities acts as a stimulus to plants, and there is a certain capacity for adaptation to poisons possessed by them, although limited. By the time the effect appears in the foliage considerable gas has been absorbed by the roots, and since it is impossible to eliminate the gas from the soil, absorption is bound to continue and the tree is doomed. We have known of only a few instances (with the exception of the conifers above noted) in which trees have shown even slight symptoms of gas poisoning and survived for any length of time. In some instances where only one root has been affected, and the poison has not reached the trunk of the tree, amputation of the root may prevent further injury, and is known to have been effective. There are many cases in which trees have not suffered from gas poisoning although located near large leaks, owing to the amputation, during the installation of curbings, etc., of the larger roots which extended over the gas pipes.

[1] **Mass. Agr. Exp. Sta. Rept. 25, 1913, Pt. I., p. 51.**

When the soil is charged with gas, digging it up and aerating it is beneficial, and in the case of severe leakage it is well to leave the trench open for a few days, if possible. On the other hand, boring holes in the soil and filling with water or lime is a perfectly useless practice. It is generally believed that if young trees are planted near others which have

FIG. 96 — Large elms killed by escaping illuminating gas, one and one-half years after leakage occurred.

died from gas poisoning, they will not live, but this is true only in some cases. If the soil is thoroughly saturated with gas, bad results will follow, but if the trees are planted in fresh loam and the old soil aerated, there is little likelihood of the tree dying.

Gas escaping into the soil from a leak follows the line of least resistance. For this reason, if leakage occurs in the street in front of a house, one can

often detect the odor of gas in the cellar, as the gas will follow the exterior of the pipe leading into the cellar, and often escapes into sewers, underground conduits, hydrants, etc. Wells are often badly contaminated even when located some distance away, and in the winter gas leakage becomes a source of danger to near-by greenhouses.

There is considerable difference in the resistance of soils to gas. In gravelly soils we have known gas to travel 2,000 feet when the ground was frozen and escape into the cellar of a house, while in heavier soils it is more likely to be restricted to smaller areas. It requires a considerable amount of gas to kill a large tree, although not so much as it would were

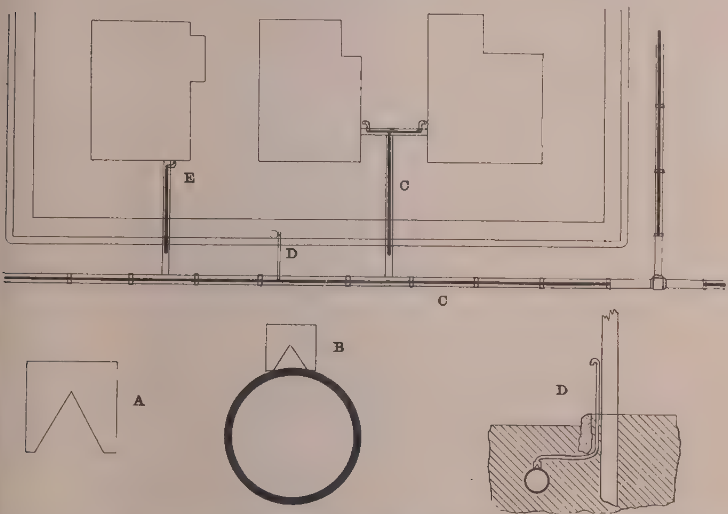

FIG. 97.—Protective arrangement against injury resulting from leakage of illuminating gas. A, cross section of protective conductor; B, adjustment of same to pipe; C, black lines showing method of arrangement of protective device on street and house service; D and E, vents for leakage.

it not confined so closely by the soil covers, especially in winter, and by the impenetrable macadam and other styles of modern roadbeds.

The danger to human life from illuminating gas is too great to be ignored, and even with the present defective systems of distribution it is not only possible but practicable largely to eliminate the dangers from this source to trees as well as to human life by the use of certain devices to prevent the leakage of gas into the soil.

The comparatively recent introduction of joints welded by the acetylene flame may prove superior to the threaded or calked cement and leaded joints in preventing leakage, but this system of laying street mains has not been thoroughly tested out in cold climates. There are also protective arrangements covering the pipes designed to prevent leakage of

gas. This protection may be secured by laying a simple device, originated and used by the writer, over the gas main to convey the leaking gas to certain points above the ground, thus preventing contamination of the soil. By using a block system or applying it to sections 100 or 200 feet long, as the case may require, and ventilating each section, a leak may be readily detected and repaired before it has an opportunity to cause any damage. The device made of chemically treated wood and shown in Fig. 97 is suitable for this purpose. It consists of pieces 2 inches square in cross-section and of any desired length. This size may be adapted to any size pipe and secured to it by wires at intervals of 6 to 12 feet (B). Each section, which may be 200 or more feet in length, is vented by means of a pipe running to a pole or tree or any convenient object (D and E), or may be vented directly over the pipe or near the sidewalk or curbing by using an ordinary iron shield provided with vent cap, such as is used for gas shut-offs. This takes care of all the leakage, conveying it into the atmosphere at certain points. If leakage occurs it can be detected by pedestrians and prevented from permeating the soil, where it would be likely to kill trees on the highway. While at present it may not be feasible to equip all pipe lines in this way, all new systems should be protected, and those already laid as fast as possible. This protection should also be extended to house services to prevent asphyxiation to human beings and injury to shrubbery and trees on private property.

Effects of Atmospheric Gases on Vegetation.

The atmosphere of industrial centers is a complex mixture of various substances. Besides the presence of the well-known gaseous constituents found in the atmosphere, — such as oxygen, nitrogen, carbon dioxide and water vapor, — hydrocarbons, solid particles and compounds of carbon, nitrogen, chlorine and sulfur are present in varying quantities. Argon, helium, krypton, neon, xenon and ozone are also found in the atmosphere in small proportions, but so far as is known they cause no detrimental effect to living organisms. Carbon dioxide, which is present in the atmosphere normally ranging from .03 to.04 per cent., is not destructive to living organisms at this dilution. On the other hand, it furnishes the most important source of food for vegetation, and plants will thrive even better with a much higher concentration than that normally existing in the atmosphere. Sulfur, which may be present in the air in several forms, constitutes one of the most injurious agencies to plant life, and sulfurous gases arising from smelters, which often contain other poisonous substances, are frequently detrimental to animal life. There exists some sulfur in most grades of coal, and during the process of combustion sulfur dioxide is given off. This pollutes the air to a certain extent, and if sufficiently abundant will injure plants. When oxygen combines with sulfur dioxide, it forms sulfur trioxide, which in turn forms sulfuric acid with water. Sulfuric acid is very corrosive, attacking and decomposing

various building materials, and is more or less injurious to plants and animals. The amount of sulfurous gases in the atmosphere, however, is often quite insignificant, and very exact methods of chemical analysis are required for quantitative determinations. The most exact and refined methods of analysis in use are hardly reliable for amounts less than 1 to 5,000,000 parts of sulfur dioxide. Particles of cement dust, such as may be found near cement manufactories, injure vegetation, as does the soot arising from incomplete combustion of coal. Moreover, dust particles, which may equal 50,000,000 to a cubic inch, form the nucleus of fogs, which in turn imprison various obnoxious gases, thus rendering the dust particles indirectly detrimental to vegetation.

Besides the injury to vegetation resulting from gases associated with smoke, smoke affects vegetation by causing a deposit of soot on the leaves, thus obstructing the light. The soot also clogs the breathing pores or stomata of the leaves, causing asphyxiation. The acids resulting from coal combustion which accompany smoke also affect the soil by producing soil acidity. At Leeds, Eng., a manufacturing city, it is estimated that the daily deposit of soot is about one-half ton, and in the vicinity of other English cities, where much soft coal is burned, the soil has become so impregnated with smoke acids as to be of much less value for agricultural purposes. Soft coal contains more sulfur than hard coal, and combustion is less complete, resulting in more smoke and solid particles, which are conducive to fogs. Fogs hold the sulfurous gases down, and in cities where considerable soft coal is burned such gases affect vegetation more severely.

Soft coal is burned on steam railroads, but the escaping smoke and gases are readily dispersed in the atmosphere. Moreover, the exposure to gases of the vegetation along railroads is of such brief duration that injury to plants is seldom noticeable. Injury to trees is frequently discernible in the vicinity of railroad engine houses, or roundhouses as they are called. Soot is often found deposited on the trunk and foliage of trees in such situations, and the contained gases affect the size and color of the leaves.

Trees in general are affected by atmospheric gases, but some are much more immune than others. The black locust, Ailanthus and peach are especially so, while most conifers and some of the oaks are quite susceptible to injury. Many herbaceous and annual plants, such as morning glory, cosmos, ragweed, etc., are very susceptible to injury from gases. Short-lived trees of rapid growth, such as poplars, willows, box elders, cottonwoods and soft maples, will survive and resist smoke and gases more readily than the oak, elm, hard maple, chestnut and linden. Our native elm appears to be affected most seriously by atmospheric gases, although the nature of the symptoms resulting from constant exposure to atmospheric gases is such that few ever guess their true significance. The pathological effects following exposure to gases indicate troubles of a chronic rather than an acute nature, and the trees gradually lose vigor

through a series of years until they finally die. There are many instances in New England, particularly in large industrial centers, where the expectation of life of elm trees is reduced from one-half to one-third the normal, owing to the presence of noxious atmospheric gases, and no amount of soil renovation or tree surgery can correct these conditions.

It is questionable whether injury ever occurs to vegetation from smoke derived from wood, although in one or two instances injury to crops has been surmised. In each case the crops were located near brick kilns.

Lichens are the most sensitive organisms to smoke, although the smoke and gases derived from wood combustion appear not to affect them. These lowly organized plants are invariably absent on trees in cities, and in the thickly inhabited parts of towns where coal is burned, but may be observed in suburban settlements where wood is more used as fuel. These organisms are apparently affected even by the minutest trace of sulfurous gases in the atmosphere.

The greatest injury to vegetation occurs near smelters, where sulfur dioxide and other gases contaminate the atmosphere. In some places vegetation is affected 75 to 100 miles from such establishments. Where sulfur is used for bleaching purposes, and the atmosphere becomes polluted, vegetation is likely to suffer, and many manufacturing establishments which make use of coal-tar products, naphtha, ammonia, carbolic acid, creosote oil, etc., frequently fill the atmosphere with poisonous gases which injure vegetation and animal life. However, the manufacture of sulfuric acid by smeltering companies has done away with much of the injury formerly occurring to vegetation in their vicinity. In the manufacture of sulfuric acid the furnace smoke, which is heavily laden with sulfur dioxide, is used, and in modern equipments most of the sulfur contents are removed. Sulfur dioxide is much heavier than air, and possesses a pungent and characteristic odor. Persons familiar with the odor of sulfur dioxide are comparatively rare who can detect 2 to 1,000,000 parts when present in the atmosphere. Even 3 to 1,000,000 parts is detected by only few, while 4 to 1,000,000 parts is discernible to those of average sensitiveness.

The limitation of injury from sulfur dioxide to the most sensitive plants, or threshold of discoloration as we term it, is according to some experimenters 1 to 1,000,000 parts. This, however, is regarded as the theoretical limit, since it would require many hours to produce visible injury to the most sensitive plant with this concentration, and, as a matter of fact, burning or visible injury probably never occurs in nature with this dilution. Very sensitive plants will show discoloration when subjected to sulfur dioxide from 3 to 4 parts to 1,000,000 if they are exposed to this concentration for a number of hours. Or, in other words, to produce burning a concentration would have to exist in the atmosphere for some hours, even when present in sufficient quantity to be discernible to the sense of smell. Burning in general from various gases presents different appearances, and the same gas will produce entirely different pathological

symptoms even in the same species. Burning from gases in general is affected by light, soil and air moisture, and the age of the foliage constitutes a factor, as probably does the condition of the stomata or breathing pores of the leaves, which vary in number from 800 to 170,000 per square inch of leaf surface.

Some recent European experiments show that burning from gases is intimately associated with sunlight, a fact long recognized by American gardeners in connection with the fumigation of greenhouses. Fogs and mists are conducive to burning. As is well known, they have a tendency to drive gases downwards, imprisoning them, as it were, and preventing their diffusion. Burning even with the same concentration of gas is more severe in moist than in dry air. Southern exposures are the most favorable to burning from gas, as are the exposed tops of trees, where the light conditions are more intense, and it has been demonstrated that burning is associated with the assimilative activity of the leaf, which is at its maximum during bright sunlight. Hence, a plant in sunlight will show discoloration or burning at a much less degree of concentration of the gas than during cloudiness or darkness, and the proportions of sulfur dioxide in the atmosphere must be considerably greater to produce the same effects under poor light conditions than during sunlight.

As the stomata or breathing pores are open during bright sunlight and closed during dull days and darkness, these organs would appear to have some influence as regards burning. However, experiments have shown that the stomata or breathing pores of the leaves, at least in some cases, close immediately when exposed to various gases, and in this way they may prevent severe injury to a certain extent. The age of the leaf is very important as regards susceptibility to burning, the younger leaves not being so susceptible to burning as the older ones. This is shown by injury from illuminating gas in greenhouses. This gas affects the older foliage, while the younger leaves remain normal or unaffected with small dosages. This may be explained in two ways, *i.e.*, that the stomata of the older leaves which are injured are more or less inactive, whereas on the younger ones they are more active. Moreover, the assimilative processes more nearly approach their maximum condition in the well-developed or older leaves than in the younger ones; or, in other words, carbon assimilation is undoubtedly more active during June and July than during April and May in some species, and as burning is associated with the assimilative activity of the foliage, burning may naturally be expected to occur more severely to older leaves than younger ones. The probability of the inactivity of the leaf stomata constituting a factor in susceptibility to burning from gases is borne out by the fact that some species which possess thick and tough leaves appear to be the most susceptible to burning, and the inability on the part of the stomata to respond to external influences may be an important factor underlying injury from gases. The condition of the atmosphere is often extremely variable even in the same locations, and any gas would be variable in its concentration,

hence one part of sulfur dioxide per million might be present for a few moments at any particular point, while a few moments later only slight traces would be found.

The preparation of asphalt and tar on streets lined with shade trees sometimes results in burning of the foliage; and this is also true of steam rollers when employed for road work.

Sewer gas has often been suspected of injuring shade trees. The constituents of this gas are, however, extremely variable. Some of them are toxic, and in sufficient quantities are capable of injuring vegetation. As a matter of fact, however, injury to plants from sewer gas seldom occurs; on the contrary, sewers and cesspools furnish one of the best environments for root growth. Even when the poisonous gases of the sewers reach rather high percentages they are seldom produced in large enough quantities to do harm, and soon become diffused in the atmosphere.

In summarizing the effects of smoke on vegetation the following factors should be considered: —

Smoke is the product of combustion diffused in the air, and may be either visible or invisible, affecting vegetation in the following ways: —

By retarding growth and development of plants in consequence of the presence in the atmosphere of noxious gases, acids, etc.

By causing a direct burning of the foliage resulting from the gases present.

By causing asphyxiation through the deposition of soot on the foliage.

By reducing the light intensity and thereby affecting photosynthesis or carbon assimilation.

By constituting an important factor in the formation of fogs, which increase the susceptibility of plants to injury from gases.

By combining with certain soil constituents to form an acid soil, thereby affecting the roots of plants.

Smoke affects plants both directly and indirectly, although the effects are often slow in asserting themselves.

The direct effects of smoke arise from the products of combustion, such as soot and sulfurous gases, which affect the foliage and young shoots, also the soil, and, consequently, the roots of plants.

The indirect effects of smoke follow as a result of fogs, which are due to the solid particles present in the smoke and which also interfere with the normal light conditions, thereby affecting photosynthesis or carbon assimilation.

The factors involved in burning from gases may be classified as follows: —

1. Inherent susceptibility to burning, which is determined by the anatomical and physiological characteristics of the organism.

2. Susceptibility of a periodic nature, which is associated with the activity of some particular life cycle function.

3. Susceptibility associated with meteorological conditions or agencies.

Electrical Injuries.

The increase in electric railroads, electric lighting systems and telephone lines, whose wires are usually located near the tree belts of our cities and towns, has made necessary a lamentable amount of disfiguring pruning. When strung too close to trees, wires also often cause serious injury by burning, sometimes mechanical injury is done, and lightning discharges will cause harm when guy wires are attached to trees.

Both the alternating and direct currents are used. They produce different physiological effects on plant life, the alternating current apparently being less injurious than the direct; and when either is used at a certain amperage it acts as a stimulus to the plant, and growth and development are accelerated.

There are minimum, optimum and maximum currents affecting plants. The minimum represents that strength of current which just perceptibly acts as a stimulus, and is very insignificant. The optimum is that producing the greatest stimulus — about .2 milliampere — and the maximum, that causing death. The maximum current necessary to cause death is very variable. The direct current has a less stimulating effect than the alternating, and on account of its electrolyzing effect is capable of causing more injury to vegetable life than the alternating current.

Most of the injury to trees from trolley or electric light currents is local, *i.e.*, the injury takes place at or near the point of contact of the wire with the tree. This injury is done in wet weather when the tree is covered with a film of water, which provides favorable conditions for leakage, the current traversing the film of water on the tree to the ground. The result of contact of a wire with a limb under these conditions is a grounding of the current and burning of the limb, due to "arcing." The vital layer and wood become injured at the point of contact, resulting in an ugly scar and sometimes the destruction of the limb or leader. In a large number of tests made by the aid of sensitive instruments with guy wire and other connections of wires to trees we have never found any leakage during fair weather or when the surface of the tree is dry. Since the amount of current that can be passed through a tree depends upon the resistance and electromotive force, we shall consider this resistance.

As might be expected, there is considerable difference in the electrical resistance of various trees as well as of the different tissues found in trees. The heartwood, sapwood, cambium, bark and sieve tubes possess quite different properties and functions, and their electrical resistance would naturally vary to a large extent. The living cells containing protoplasm, such as are found in the cambium, present the least resistance, as shown by various observations on lightning discharges. The minute burned channel caused by comparatively insignificant lightning discharges follows down the cambium, indicating that this is the line of least resistance. Moreover, by driving electrodes into a tree to different depths and measuring the resistance it can be shown that the least resistance occurs in the region of the cambium.

The electrical resistance may average throughout the year about 25,000 ohms in 10 feet of the trunk of a large maple tree, but in cold weather it often exceeds 100,000 ohms. The lowest resistance in all cases corresponds to periods of high temperatures, and the highest to periods of the lowest temperature. The difference shown by the various sides of the tree is also related to temperature. The resistance of the sapwood is very much greater, and probably that of the heartwood is even higher than that of the sapwood.

In determining the electrical resistance it is necessary to know the path or course of the current, and the only manner in which the resistance of different tissues can be determined accurately is by isolating the tissues. By girdling a tree and scraping the trunk down to the solid wood we can get the resistance of the wood. Mr. G. H. Chapman[1] found the resistance of a freshly cut rock maple stem, $1\frac{1}{2}$ inches in diameter, to be 70,000 ohms with the bark on, but 150,000 ohms when the bark was removed. The electrodes were 1 foot apart. Next to the cambium the phloëm has the least resistance, followed by the sapwood. The outer bark appears to offer the most resistance, but when wet the resistance may be decreased, owing to the less resistant film of moisture on the bark. The resistance obtained from an elm tree in summer, with the electrodes 10 feet apart and in contact with the cambium, was 10,698 ohms, whereas when the electrodes were inserted into the middle of the cortex or phloëm we obtained 11,300 ohms' resistance. When driven one-quarter inch into the wood, and some of the exterior tissues surrounding the electrodes removed, the resistance was 98,700 ohms. The outer bark gave 198,800 ohms' resistance, but when the electrodes were inserted slightly deeper into the bark we obtained 109,900 ohms. It should be pointed out, however, that the data given here do not represent the actual resistances of the various tissues, but they indicate that there exist very material differences in the electrical resistance of the tissues in trees. The resistance obtained for the cambium, however, may be taken as fairly representative, as shown by the use of other methods, such as the employment of relatively high potentials and current measurements.

The resistance given by small tree trunks and woody stems, even for small distances, is quite large. About 4 feet of a young pear tree, including the root system, with a maximum diameter of stem equal to 1 inch, gave a resistance of about 300,000 ohms; and the resistance given by a tobacco plant, in which the distance between the electrodes was only 14 inches, was much higher (110,000 to 165,000 ohms) than that shown by trees at corresponding temperatures.

The water and various salts in the living plant undoubtedly play a rôle in resistance, and it might be expected that the various plastic substances would influence it also.

The cambium ring is very insignificant in size, and even on a large tree the total area is small. In all probability it is the protoplasm itself which

[1] Mass. Agr. Exp. Sta. Rept. 24, Pt. I., 1912; also Bulletins 91 and 156.

offers the least resistance to the transmission of an electric current; and even if there were no continuity it would be necessary for the current to pass through a great many cell walls even for comparatively short distances on the trunk. In case the protoplasm was continuous or there existed continuity, the strands would be so very small that they would undoubtedly offer high resistance, due to their attenuation. Whatever conditions prevail, trees show relatively high electrical resistances, a feature which is no doubt of some biological importance. The high resistance of trees, moreover, is undoubtedly a protection in case of lightning strokes, since often the heat developed is enough to do only slight injury. On the other hand, if trees possessed tissue with relatively small electrical resistance, they would be more seriously affected by currents from high-tension wires. The electrical resistance of trees is so high that it is doubtful whether injury ever occurs to them from contact with low or even high-tension wires, except that produced by grounding when the bark is moist. Any escaping current from transmission lines that can be transmitted even through the least resistant tissue is likely to be insignificant.

FIG. 98. — Showing disfigurement of trees caused by high-tension alternating current wires.

Effects of Alternating Currents.

The alternating current systems employed for lighting purposes vary greatly in their potential. Cases of burning from alternating currents are more numerous than those from direct currents because trees are brought into more frequent contact with the wires, and, owing to the higher potential, more leakage is likely to occur. The high and low voltage lines may vary from 100 to 100,000 volts. The high-tension systems are invariably constructed across country, and are naturally not brought into very close proximity to shade trees. No injury to trees whatever occurs

from the low voltage (110-volt) lines, but the lines of higher potential found on streets constitute a source of danger to trees. The higher the electrical potential the more dangerous the wires become to trees, for, owing to the lessened effectiveness of the ordinary insulation, more leakage occurs and consequently greater opportunity for burning.

The effects of alternating currents on trees are local, producing injury only near the point of contact with the wire. Such contact results in death of that part of the tree, and if it is a leader or large limb it usually has to be sacrificed. In no case, to our knowledge, has an alternating current caused the death of a tree, although it may burn or disfigure the tree so badly that it amounts to practically the same thing. It is doubtful whether the current from a fairly high potential wire would kill a large tree under any circumstances. It is different in the case of small plants, as has been frequently demonstrated in the laboratory, although the current must produce heat enough to kill the protoplasm. The close relationship between the maximum temperature required to kill a plant and that induced by electrical current indicates that the collapse of the plant tissue in such cases is probably due to the heat rather than to any specific electrical shock. It is possible to pass the same current through larger plants where heat is not generated without causing any collapse of the tissue. The ordinary house circuit wires are perfectly harmless to trees, and it seems strange that a judge could render a verdict to the effect that an ordinary insulated 110-volt house circuit was responsible for the death of a tree whose terminal branches were located 3 feet from it. There is only one court record of which we know where such a judgment has been given.

Very high-tension line wires are not provided with insulation and are known to affect the atmosphere surrounding them to a considerable extent. Any increase in the electrical potential of the atmosphere if not too high would favorably affect vegetation in general.[1]

General Effects of Direct Currents.

Most of the direct currents affecting trees are those used for operating electric railroads. Trolley feeders may be at 500 to 550 volts. Ordinarily the burning from direct currents is similar to that produced by the alternating current in being largely local or confined mainly to the point of contact with the wires. The feed wires cause no burning except when the tree is moist, in which case grounding takes place.

The strength of current which will kill one plant will produce not the slightest effect on another; in other words, the maximum current for each individual varies materially. Small, tender plants possess a maximum much below that of woody plants. A young, succulent tomato

[1] There is evidently much difference in plants in this respect. A crop of radishes showed a gain of 57 per cent. when subjected to an average atmospheric potential of 167 volts, whereas an electrical potential equal to 500 or 1,000 volts is beyond the stimulation zone for some plants (16th Ann. Rept. Mass. Agr. Exp. Sta. (Hatch), 1904, p. 31).

plant, one-eighth inch in diameter and 5 inches high, was instantly killed when treated with a current of 20 milliamperes, and currents of 2 and 3 milliamperes of thirty to sixty seconds' duration accomplished the same result. In all the tomato plants, considerable heat was developed, and their death was caused by the generation of heat developed by the current. The electrodes in these tests were about one-half inch apart. If the electrodes had been farther apart, no perceptible effect would have been observed.

When trees with a more or less thick bark are drenched with rain the conditions are quite different. A large maple tree which was in circuit with a feed wire (500 volts) and rail of an electric road when dry gave a current equal to 70 milliamperes (one-fourteenth ampere) with the electrodes placed vertically 1 foot apart. These connections were left on the tree for several months. The observations were made on dry days and no appreciable amount of heat developed with this current. During periods of wet weather considerable heat always developed, especially at the positive electrode, but not enough to melt the soft solder which connected the wires with the electrodes.

Examination of the tree ten months later showed that a portion of the tissues near the electrodes had been killed. After removing the dead bark an oval space 6 by 11 inches was found to be dead about the positive electrode and a space about $1\frac{1}{2}$ by 3 inches near the negative electrode. The burned area about the positive electrode was about 95 per cent. greater than that occurring about the negative electrode; in each case it extended about twice as far above and below the point of contact as out to the sides of the electrodes, thus showing a tendency of the current to spread laterally as well as vertically, but more largely vertically. The immediate area around the electrodes was more affected than that farther remote. There was an area of tissue about 5 inches long between the large and small oval burning that was uninjured, showing that burning was confined about the electrodes. The current traversing the film of water on the bark between the electrodes was not sufficient to destroy the tissues at that point.

If a milliammeter had been placed in the circuit when the tree was wet a greatly increased current would have been detected, since the current in this case traversed the less resistant film of moisture on the bark. But the electrical resistance of the vital layer under such conditions would remain practically the same as when the tree was dry, or it would show only such variation as might be induced by an increase in temperature. The burning and injury in this case resulted from the heating of the film of moisture, which became so intensely heated that the vital tissue was destroyed, especially near the point of insertion of the electrodes. The more the film became heated the greater was the lessening of the resistance and increase of the current.

Practically all of the burning of trees from either alternating or direct

currents occurs in this way, since the high electrical resistance characteristic of trees does not permit injurious currents to pass through their tissues.

Death of Trees from Direct Current.

Instances are known in which large trees have been killed by direct currents used in operating electric railroads. Attention was first called to these cases in Bulletin No. 91, issued by this station, and since the publication of this bulletin other cases have been observed. In all of these cases the escaping current had burned and girdled the trunks for a distance of from 5 to 10 feet from the base; the point of contact of the feed wire with the limb 18 or 20 feet above showing little or none of the characteristic local burning effects usually observed in ordinary cases of grounding. In fact, the difference between the burning from direct currents in these cases and that from ordinary cases of electrical injury may be seen at a glance. On electric railroad systems the so-called positive current generally traverses the overhead feed wire, where the injury (burning) takes place. It does not differ materially from that produced by low-tension alternating current wires. In all cases of death from direct-current electricity that have come to our notice, however, the rail was positive and the overhead wire was negative, constituting what is called a "reversed polarity." How common this practice is we cannot say, but apparently it has been employed intentionally at times to prevent electrolysis as well as unintentionally by various companies, and is responsible in a few instances for the death of shade trees near electric railroads. There is much greater opportunity for extensive burning in the case of reversed polarity than in the regular systems employed. The moisture conditions of the soil and bark are such as to reduce the resistance, and in consequence the film of water and the water-soaked bark

FIG. 99. — Showing elm tree killed by direct current (reversed polarity) from electric railway system. Note effects of burning at the base of the tree.

become intensely heated, destroying the living tissues and girdling the tree to a considerable distance. The part of the trunk towards the rail is almost invariably the most severely affected. With reversed polarity, as already pointed out, the injury is confined mainly to the base of the trunk, where the destruction of tissues causes great damage. Such damage does not occur when a positive overhead feed wire comes into contact with limbs. The entire area between the base of the tree and the overhead wire is not, as a rule, affected, although the extent of injury may vary somewhat. On the elm shown in Fig. 99 the burning was caused by a reversed system, and there was only slight injury at the point of contact with the overhead wire, while at the base about 6 or 7 feet of the tree were affected. This injury takes place when the soil and the bark of the tree are moist, and may occur during a single period of excessive moisture, or intermittently. In some instances trees show serious effects a short time after the current has been reversed, when the bark will become loose and later fall off. The writer has observed both elms and maples — some of them 2 feet or more in diameter — which have been killed in this way. In some cases the trees were not more than 3 feet from the rails, while in others the distance was considerably greater.

In one city, 51 trees were reported killed or so badly injured as to be of no value, 67 had large limbs removed, and many more were saved by removing limbs likely to come into contact with wires. Some of the injury took place on streets having trolley wires but no electric railways, and it is surmised that the ground connections were made through several pipe lines located near the trees, which led very close to the electric railway. According to Mr. G. A. Cromie,[1] who had these under observation, the injured trees were in some cases located from 200 to 1,000 feet from the track. The effects on the trees were noted shortly after the street railway had changed its system, *i.e.*, using the rail to carry the positive and the overhead wire the negative or return current. The trees in contact with the overhead wires became electrically charged, and when wet it was impossible for linemen to work on them. Under these conditions the insulation was much less efficient, and even wooden sleeves imbedded in coal tar and rubber proved of small use in preventing leakage. A large percentage showed a characteristic burning at the base, and the bark was burned off in some instances to quite an extent. One limb that had been in contact with the negative feed wire was found dead, but the tissue at the base of the trunk was normal. Dr. J. W. Toumey, director of the Yale Forestry School, who examined many of these trees, found a disintegration of the wire where it came into contact with the limbs, apparently due to electrolytic action, and chemical analysis showed the presence of copper and zinc in the tissues of the wood that had been in contact with the negative or overhead wire. Dr. Toumey believes that in such cases the disintegration of the copper wire and the absorption of the copper by the tissue were responsible for the death of the limbs. If

[1] G. A. Cromie, "Scientific American" supplement, No. 1985, p. 40, Jan. 17, 1914.

true, this entirely new state of affairs would indicate that the electrical injury from direct currents arises not only from heat but also from the electrical disintegration of metals, which may poison the tissues. These observations demonstrate that we have a variety of conditions to deal with in considering the effect of direct-current electricity on trees, and these phenomena may be summarized as follows: —

Burning and injury to plant tissue are much more prominent at points with a positive potential[1] *than at points with a negative potential.*

When the rail is at a positive potential and the overhead wire which touches some part of the tree is negative, and the bark and soil are saturated with moisture, a circuit is formed by means of this surface moisture.

The moisture conditions and the electrical resistance, etc., at the base of the tree are different from those above; therefore, a larger area of tissue is affected by the positively charged rail.

As the bark becomes heated through the film of water, the electrical resistance is reduced and the current increased to such an extent that the vital layer is destroyed.

The actual current passing through the inner tissues must necessarily be insignificant, and when there is a film of water on the bark, probably no current passes through the cambium; furthermore, the moist soil between the rail and the trunk of the tree becomes a better conductor for the current than the roots. The actual injury, therefore, is done by the current traversing the film of water rather than any of the inner tissues. The maximum heat and the areas most affected are near the base of the trunk.

In regard to the possibility of injury to large trees by direct currents passing directly through them, experiments show that what holds true for alternating currents is true also to a great extent of direct currents. However, it would require a voltage much higher than that furnished by most electrical railways at the present time.

It might be possible for direct currents to affect trees without causing any perceptible burning. If, for example, a tree were subjected to a sufficient strength of current, there might occur a disintegration of the cell contents, causing the tissues to become abnormal and finally to die, but the electrical resistance of trees is so great that a quite high potential would be necessary. If the potential of the electric railway systems were greatly increased, it is possible that some injury might result to trees even under ordinary conditions.

Probably the amount of ground leakage occurring through imperfect rail connections would not cause any perceptible injury to trees; nor is there any direct evidence that lightning arresters when placed near trees cause any injury by discharges. However, the guy wires used by

[1] Positive electro-static charges have a more stimulating effect on plants than negative charges, and retardation of growth and injury to the cells are more pronounced. The phenomena associated with the positive and negative galvanotropic bendings of roots may be explained in this way (24th Ann. Rept. Mass. Agr. Exp. Sta., Pt. I., p. 144, 1912).

electric systems are a source of danger from lightning, and we have observed cases where large limbs have been destroyed and the trunks of the trees badly lacerated by electrical discharges from these wires.

On the whole, the cases of death to trees from electricity are by no means so numerous as is generally believed. Because a large number of

FIG. 100.—Showing electrolysis of gas pipes. (After A. A. Knudson, "Corrosion of Metals by Electrolysis.")

trees near electric roads, etc., often look sickly it must not be concluded that electricity is always the cause. In cities and towns, where most of these unhealthy specimens are found, there are innumerable destructive factors for trees to contend with. It is quite essential in diagnosis work, therefore, that all of these factors be taken into consideration before a definite opinion in regard to the cause of any abnormal condition is formed.

Electrolysis.

Direct current electricity is frequently responsible for electrolysis of gas and water mains, and lead coverings of underground telegraph circuits are often affected. The trouble is often so serious that the iron gas and water pipes become corroded and eaten with holes in a few weeks or months, causing leakage. When gas mains are affected by electrolysis, the gas escapes and permeates the soil, so that electricity sometimes becomes a primary and gas a secondary factor in the death of trees.

The phenomena associated with electrolysis are often complex and difficult to do away with entirely, according to expert electricians, but much of the trouble can be eliminated by proper bonding of the rails of electric roads and the grounding of different systems.

Electrolysis is more common in wet than in dry soils. Cases are on record where severe electrolysis has taken place 700 or mor[illegible] from the source of the leakage. It more often becomes troublesom[illegible] where numerous railways and public-service corporations of all [illegible]s make use of the streets. We have observed cases where plants have [illegible]timulated and their growth increased by escaping electricity in the soil.

Lightning.

The common effects of lightning strokes on trees are so well known that it is not necessary to dwell upon them here; but lightning does not always strike a tree in the same way, and the peculiar effects sometimes produced are often interesting. Very powerful discharges of lightning act somewhat

like an avalanche, causing a severe shattering of the tissue, while less powerful discharges may remove a strip of wood only a few inches wide and 1 or 2 inches thick. Lightning often takes a spiral course, following the grain of the wood, which is sometimes very irregular. Even when strips of wood 4 or 5 inches wide and 2 or 3 inches thick are removed, in which case the electrical energy is enormous, the path of the discharge is shown only by a dark-colored streak 2 or 3 millimeters wide.

FIG. 101.— Showing ridge on elm tree caused by feeble lightning discharge.

Sometimes trees are killed outright by lightning without being shattered or displaying any other of the common effects. In such cases the discharge is apparently dispersed so as to cause no visible mechanical injury to the tree, but the girdling of a large or small area of the living zone or cambium layer of the trunk would be sufficient to cause its death. This might follow as a result of an earth discharge either destroying the vital tissue directly or by a dissipation of heat over a surface film of moisture. In some instances the leaves wilt immediately and die, indicating injury from heat. However, in a very large number of instances neither death nor mechanical injury of any importance takes place. Hundreds of trees are annually struck by lightning that never show any effects except to those capable of interpreting the small narrow ridges which later make their appearance on the trunk. In such cases the lightning discharge follows the line of least resistance, — the cambium zone, — burning a small channel usually about 1 millimeter in diameter. The tissues surrounding the channel are apparently not injured, but the annular rings which are later formed outside the burned channel are much broader, resulting in the formation of a ridge on the bark.

Earth Discharges. — There are many cases of lightning that are apparently earth discharges. Their effect on the tree is quite characteristic and not at all similar to the ordinary forms of lightning strokes. Our attention was called several years ago to some shade trees to which lightning had apparently caused some injury. These trees were maples 5 to 18 inches in diameter, growing in soil composed mainly of gravel containing oxide of iron, and underneath this a stratum of quicksand. A considerable number of the trees showed the effects of repeated earth discharges, in some cases becoming so disfigured that they had to be replaced for the third time. These discharges occur during thunderstorms, and those who have observed them for many years relate that they give rise to a dull, characteristic report resembling that caused by throwing a wet

cloth on a hard surface. The whole tree is not affected as a rule, as the lightning stroke seldom follows up the main trunk, but discharges at the points of several branches. As a rule, however, one side of the trunk and one or more of the limbs on that side are affected and the symmetry of the tree destroyed. The first indication of the discharge is shown by the immediate wilting and subsequent death of the leaves of the affected limbs, which also die later. In the course of time cracks similar to those caused by frost, and later ridges due to healing, will be seen on the trunk, showing the path of the discharge, and occasionally, when the injury is considerable, the bark near the affected part of the tree falls off. The limbs, however, are not always killed, frequently splitting, and a cracking of the wood for some depth is now and then observed on the trunk and limbs along the path of discharge.

FIG. 102. — Maple showing effects of earth discharges (lightning), causing splitting of the trunk and death of limbs.

Whether the chemical composition of the soil has any particular bearing on earth discharges is not positively known. It is known, however, that there frequently exist great differences in the electrical potential between the earth and air during thunderstorms, and that the electrical conditions of the atmosphere and earth may change instantly from negative to positive. Some observations made in our laboratory with a Thomson self-recording quadrant electrometer show that the electrical potential of the atmosphere, at a distance of 30 feet from the ground, may vary, often in a brief period, from a few volts to 300 or more. It is also known that trees occasionally discharge sparks at their apices, showing that insignificant earth discharges occur through trees; and when the soil in which potted plants are growing is charged electrostatically, small sparks are thrown off from the leaves. Earth discharges through trees, whether strong or weak, appear to be similar in nature, and may be associated

with changes in the potential of the earth and atmosphere. The high electrical resistance shown by plants in general, as already stated, serves as a great protection against death from lightning and electric currents.

Susceptibility of Different Trees to Lightning Stroke. — There has always been much difference of opinion in regard to the susceptibility and non-susceptibility of various trees to lightning, and the data of the subject gathered from this and that source are altogether too meager to admit of reliable conclusions; but it is known that the location of the tree, nature of the soil, elevation, etc., are of great importance in determining susceptibility to lightning.

It has already been pointed out that electrical resistance is influenced by temperature, and the percentage of moisture in the tissues is also an important factor. During thundershowers, trees become more or less drenched with rain, and, according to Stahl,[1] the more thoroughly wet the tree is the less susceptible it becomes to lightning stroke. He bases his observations on the fact that smooth-bark trees, like the beech and others, which are considered more immune to lightning, become thoroughly wet during storms, while the oak and other rough-bark trees do not. Stahl's idea, therefore, is that smooth-bark trees possess a better water-conducting surface and have a tendency to equalize the electrical tension existing between the atmosphere and the ground, so that they are rendered less susceptible to lightning. His deductions were based upon experiments with electrical discharges made with the bark of different species of trees containing various percentages of moisture. He further observed that vertical limbs were more likely to become drenched than horizontal, and that the lenticels and stomata play a rôle in the equalization of the difference in electrical potential existing between the tissues and the atmosphere. There appears to be no difference in the electrical potential, at corresponding heights, under deciduous trees and in the open air when there is no foliage, while the electrical potential will average 40 per cent. less under the trees than in the open air when the foliage is developed.

The potential of the air is usually negative, although occasionally changing to positive. In the case of coniferous trees, however, like the Norway spruce,[2] we found that the potential under the foliage was invariably positive or similar to that of the earth, which may be explained on the theory that conifers are constantly discharging positive electricity to such an extent that the air surrounding them becomes charged similar to the earth. To what extent the film of water on the bark is capable of equalizing the difference in electrical potential in the air surrounding the trees, as well as in the ground and in the tissues themselves, has not been wholly determined, but we had difficulty in obtaining potential readings under the foliage of elms in wet weather in our experiments covering two summers. This may in part be explained by the improper installa-

[1] Stahl, E. Die Blitzgefährdung der verschiedenen Baumarten, Jena, G. Fisher, 1912.

[2] Mass. (Hatch) Agr. Exp. Sta. Rept., 1905, p. 14.

tion of our collector. It is not unlikely that the film of water on the bark of trees during such periods would have a tendency to affect materially the potential of the surrounding air, as Stahl has pointed out, and possibly to equalize the electrical tension. The subject should have further investigation, but we believe that it is possible to protect trees from injury by lightning, whether they be atmospheric or earth discharges.

Injuries to Trees from Arc Lamps.

Damage to trees from artificial light rarely occurs. We know of only one instance where any definite injury has occurred to trees from the use of the arc light. Mr. William G. Keith, gas and electric light commissioner of Chicago, Ill., has reported a case where the electric lights caused damage to adjacent trees located on certain streets in Chicago. The trees injured were in all cases young Carolina poplars. The particular lamps causing the trouble were known as the G. E. Company, type W, 10 ampere, 465 watt, 1,000 candle-power, series flame arc lamps, and were operated on the same circuits. These lamps were in operation nearly a year. Shortly after their installation damage occurred to the poplars adjacent to the lamps. The damage to the trees in all cases was confined to that side near the source of light, the trees being stripped of leaves and some of the branches apparently killed. The injury to the branches was such that they became infested with borers. As the injury to the trees seemed to be persistent where this type of lamp was employed and not noticeable where other types of lamps were used, — such as the direct-current open arc lamp and the 300-watt 600-candle-power gas-filled incandescent lamp, — the system was changed to the latter type, and the trees became normal, throwing out new twigs and leaves.

At first it was thought that the heat generated by the lamps was responsible for the damage to the trees, but the heat generated from the gas-filled lamps was equal to or greater than that from the other types; hence it appeared that the damage did not result from the heat. Finally it was demonstrated that the trouble was caused by the practice of emptying the contents of the globes, consisting of such products of combustion as fluorides and possibly other injurious salts which accumulate in them. The trees were located very close to the lamps and somewhat below them; hence in emptying the globes the poisonous products would fall on the foliage. As already stated, the injury in all cases occurred on that portion of the tree adjacent to the lamp, the other or remote portions being unaffected.

This is apparently the first authentic case at least of noticeable injury to street trees from electric lamps, and the theory of Commissioner Keith relative to the specific cause of the injury to the foliage — namely, it being due to the deposition of the products of combustion from the carbon on the foliage — appears to be a most rational one. It should be pointed out, however, that there are other ways in which injury of a similar nature might occur to trees from electric lights, and as innovations in

street lighting systems are frequent, attention should be given to this subject by those having the welfare of trees in their charge.

It would, of course, be possible for injury to be produced directly to the foliage of trees in close proximity to lamps resulting from the intense heat produced by the electric current setting free poisonous gases from the heated carbons used for lighting purposes, the carbons in such instances being composed of or containing chemical substances which when volatilized by intense heat and diffused in the atmosphere would be toxic to plants.

Moreover, it is possible for light itself to affect vegetation detrimentally. It is well known that artificial lights differ from sunlight very materially, and in proportion as they are characterized by rays of high refrangibility they produce abnormal conditions on vegetation. However, the injurious effects to plants resulting from various artificial lights can be and are eliminated to a large extent by the use of globes and glass screens. We have never observed, however, any detrimental effects upon shade trees from any lighting system which could be attributed to any peculiarity in the nature of the light itself.

The carbons in the older type of arc lamps which have been extensively used are supposed to be pure, while those used in the flame arc contain certain admixtures, such as fluorides. The older type of arc lamps provided with pure carbons were apparently harmless to street trees and to vegetation in general when the light was properly screened through glass, although more or less delicate, rapid-growing plants became abnormal when subject to the naked arc.

Apparently the flame arc lamps have not as yet been extensively employed on street circuits, and if the trouble to trees resulting from their use is caused by the deposition of the products of combustion of the carbons on the foliage, which appears to be the most rational explanation, it is not likely that any serious difficulty to street trees will follow their use if ordinary care is given to the handling of the residue which gathers in the globes.

Injury to Trees from Wires.

The constantly increasing use of electricity for various purposes makes necessary a more extensive use of wires, which has become a great menace to shade trees. The appearance of streets is injured by the increased number of poles and wires, and the legal restrictions as to the height, distance apart, etc., of the wires of the telephone, telegraph, trolley and electric light companies make the problem of maintaining shade trees on the same street with public-service corporations a serious one. Of all the troubles with which tree wardens have to contend, the wire problem is often regarded as the worst. Notwithstanding the strict laws which some States have adopted in regard to injuring shade trees, the agents of some public-service corporations often have little regard for trees or the laws respecting them. Where 40-foot poles must carry the wires of three or four public-

service corporations there can be little or no opportunity to preserve the natural symmetry of shade trees, especially when low branching maples and other trees are planted on the same side of the street with the wires. There is less interference from limbs with low than with high tension wires. Trees like the elm, whose branches form acute angles, offer less obstruction to wires than maples; but not all streets, of course, are planted with elms, which may be as well, considering their susceptibility to various pests and unfavorable climatic conditions.

The best solution of the wire problem lies in burying the wires. This has been done to quite an extent in large cities, especially in the business sections, the telephone corporations having adopted this system to a much greater extent than the electric light companies. It is an expensive system, however, and those who so strenuously advocate its adoption do not always consider that in the end it is the patrons who have to pay for it.

FIG. 103. — Showing the destructive effect on the growth of a maple tree of a mass of wires.

Another method of preventing wire injuries is the erection of high poles to bring the wires over the trees. This is sometimes done, especially where the trees are young or of a species that naturally grows low, when a very high pole would be sufficient to clear them for many years. The cable system may be used for telephone wires, and much injury to trees prevented. Large cables are rather expensive to install, but what is termed the "ring construction" system may be used to advantage in many instances, particularly in the suburbs. In this way it is possible to run a line through avenues of fine trees in the country districts without necessitating pruning or disfiguration.

Rights of way for poles on private property back of residences are sometimes secured, and by this means the poles and wires may be removed from the streets, much to the advantage of the trees. But such rights are often difficult to secure, and are not always satisfactory either to the public-service corporations or the owners of the property. The former naturally do not care much for these rights of way unless they are legal and permanent, and the owners in granting permanent rights run a risk of lowering the value of the property. Most of the very high-tension

transmission services, however, are at present on private property and seldom interfere with trees. High-tension lines are affected seriously merely by close proximity to trees; therefore, these rights of way have to include broad strips of land, which of course is expensive.

On general principles, it is not wise to allow wires to be attached to trees, although this is often done. Trolley and electric light wires are frequently guyed to trees, but they are a source of danger, since injury is likely to occur from the crossing of the wires, and lightning discharges occasionally pass from the wires to the tree, causing damage. It is, however, often better to allow this than to allow the erection of ugly poles; but proper insulation of the wires should be insisted on, although ordinary insulators have little effect on lightning discharges. The lagbolt system in common use for guying wires to trees is not the best method, for sooner or later the wire and bolt become imbedded in the tree and cause injury. Moreover, a direct metal connection with a tree is objectionable, as has in more than one instance been proved. The block system is better, although it may not in all cases be free from objections. (See Fig. 42.) In no case should a wire be allowed to pass tightly around a tree, as it will girdle it in time. When live wires come into contact with limbs, some type of insulator should be employed similar to that shown in (1), Fig. 105, of which there are various types, some being quite effective in preventing injury from low-voltage lines. The type shown in (2), Fig. 105, is cumbersome and unsightly, but is one of the most effective. The principle of the porcelain and dowel insulator is good, but it has a tendency to slide on the wires and to become displaced. If it were provided with larger dowels, and the danger of displacement on the wires done away with, it would prove much more satisfactory.

FIG. 104. — Showing maple tree injured by lightning discharge from trolley guy wire, causing death of limb and laceration of trunk.

Wires often accidentally come into contact with trees by the displacement of poles, particularly on curves where the strain is very great, but much of this injury may be prevented by imbedding the poles in Portland cement. It should be pointed out that the necessity for guying poles to trees may be obviated in this way.

Better methods of handling this vexatious question of wires and shade trees should be forthcoming in the future, and even at the present there must be a compromise between the tree warden or city forester and the companies as to the best method of wiring through tree belts and the amount of pruning allowed. Conditions at present favor the corporations,

as they are furnishing valuable and necessary facilities for business, and in towns they obtain their franchises and location of poles from the selectmen with little difficulty. The selectmen notify the abutters of any contemplated installations of poles and wires or of changes to occur in the systems, and the abutters are given a hearing. However, they usually wake up to their duty only after the installation of the lines, when the tree warden must assume all responsibility for injury to trees. He has to choose between two courses, — prevent the pruning or permit it. In either case the companies can erect the poles and install the wires, allowing the wires to burn their way through the trees, although this, of course,

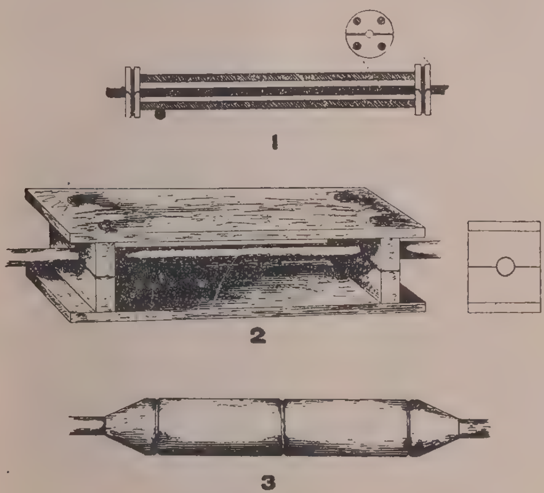

FIG. 105. — Showing different types of guards for electric wires: 1, porcelain dowel guard; 2, porcelain wood guard; 3, wooden sleeve.

often causes trouble to the corporation as well as to the abutter. In case of injury to trees the warden has access to the courts, but most companies are willing to put up with a few moderate fines for the sake of the right of way through a tree belt.

The Spraying of Shade Trees.

The great value and economic importance of spraying shade and fruit trees have resulted in placing on the market a large variety of fungicides and insecticides and types of machinery. Massachusetts has unfortunately been obliged to spend more money in spraying than any other State, and many towns and cities in the eastern part of the State, where the brown-tail and gypsy moths are so prevalent, appropriate thousands of dollars yearly for spraying.

Besides the larger spraying enterprises which are being carried on for the suppression of the gypsy and brown-tail moths, much private work is being done, and hundreds of tons of arsenate of lead are used annually in this work. While the above-named pests have not at present invaded the central and western parts of the State to any extent, other pests necessitate spraying our shade trees.

For years a great deal of attention has been given to the improvement of spraying machines, nozzles, etc. It has often been a question whether our towns or cities can afford to use the methods which are recommended and practiced by the best orchardists for shade trees. The aim of the orchardists is to cover every part of the tree which needs protection with a very fine mist spray. This method cannot be too closely followed by orchardists, since it is not necessarily expensive when only orchard trees and small fruits and crops, such as potatoes, are concerned. However

FIG. 106. — Large spraying equipment.

when we have to spray large elms, the question becomes an entirely different one.

A few years ago some large elms located in the public square in one of our cities were sprayed by the same methods used by the best orchardists, at an expense of something like $16 per tree. These trees, to be sure, were unusually large, but the cost was so great that in our opinion it set a limit to the amount of spraying which should be undertaken by such methods. Most of the former spraying of shade trees was done by this very expensive method at a cost of $1.50 upwards for trees 14 to 18 inches in diameter. In much of this early spraying the Vermorel, Ware or similar fine-spray nozzles on poles were used, and spraying had to be done at close range for the best results. The early gypsy moth work was done in this same way, any other method at that time being considered useless. This method entailed a great deal of climbing on the part of the sprayers, and was a slow and costly process. With the improvement of gasoline engines,

pumps, etc., together with the utilization of coarse nozzles, more efficient methods came into vogue. Some years ago the Gypsy Moth Commission abandoned these fine nozzles and close-range methods of spraying, and at the present time use is made only of wide aperture nozzles and solid streams, with large hose. Exceptionally high pressure is obtained from powerful machine sprayers. With the larger area which has to be treated at the present day the older method would prove prohibitory, not only on account of the expense, but also because of the time involved. Virtually all the spraying with these large modern machines is done from the ground, doing away with the necessity for ladders and for climbing trees; and by using one or more lengths of hose large areas may be treated from one spot. This method of spraying trees is very effective and very much cheaper, the average cost of spraying woodlands being something like $6 or less per acre. With this method the spraying mixture is delivered to the nozzle through a large strong hose 1 inch in diameter, under a pressure of 200 to 275 pounds, the high pressure breaking the spray up into a fine mist. The spray has considerable spread when broken up, which is a desirable feature in treating woodlands and country roadsides, but on this account it is more or less objectionable for use on residential streets in cities and towns, as it is likely to disfigure anything it touches. The high-pressure, solid-stream equipments are the cheapest, and are more practical for shade tree work than anything that has as yet been devised.

Fig. 107. — Spraying from the ground with solid stream and high pressure (Worthley nozzle).

What might be termed a compromise between the fine-nozzle system and the high-pressure, coarse-nozzle or solid-stream system employed in the gypsy moth work is often used in spraying shade trees at the present day. This consists in the use of the Bordeaux nozzle, which has an aperture of about three thirty-seconds of an inch. When used on a hand

pump with a pressure of from 50 to 70 pounds, or even more, it does not give, in our estimation, a satisfactory spray because it is not broken up sufficiently. When a small number of trees is to be sprayed and an expensive equipment cannot be afforded, small hand pumps will do the work, but when it becomes necessary to spray 500 or 1,000 trees in the course of a few weeks, power sprayers are necessary and more economical.

The Bordeaux nozzle has the advantage of being adjustable and can be used either as a mist nozzle or at more or less long distance. As a long-distance nozzle, however, under any pressure, it is unsatisfactory and much inferior to other long-distance sprays. Moreover, with the use of the Bordeaux nozzle it becomes necessary to use a ladder and to do some climbing. The aperture is so small that with any pressure the stream is limited in its height.

FIG. 108. — "M. A. C." nozzle spray with high-pressure and atomizing point intercepting the stream.

The most important factors necessary for economical work in spraying shade trees on a large scale are machines powerful enough to maintain a constantly high pressure, an efficient nozzle, and competent men to do the work. By high pressure we mean a pressure of 200 to 250 pounds, preferably the latter. This should be maintained constantly, and the capacity should be sufficient to maintain this pressure in a 1-inch delivery hose, if necessary, provided with a nozzle with an aperture one-quarter inch or more in size. With the mist nozzles, or even with the Bordeaux nozzle, a pressure of over 150 pounds is useless and unnecessary. With this pressure, or even less, depending on the nature of the nozzle employed, the maximum results may be obtained. It is extremely important for the best work in spraying that there should be as little friction as possible. Therefore, care should be exercised to have no reducing valves or couplings anywhere on the line to reduce the volume, since it is essential to have an uninterrupted flow of the spraying mixture directly to the nozzle. In this respect the fixtures usually found on the market are poorly adapted to good work, and are often useless, with the

exception of those used by the State in spraying for the gypsy moth. These are excellent.

Too much attention cannot be given to the nozzle. It should be adapted to the work required of it, and a satisfactory or ideal nozzle is worth almost any price. It should be constructed on mechanical principles which will enable it to break up the spraying mixture into as fine a mist as possible, and to do this at a distance convenient for the economical spraying of trees. The ideal nozzle for spraying either from the ground or from a ladder should possess some carrying features, and still break up the spray finely. The nozzle should not be encumbered, any more than the hose, with worthless mechanical devices which produce friction without adding anything to its efficiency, and for this reason we believe that it is better to employ mechanical devices to break up the spray after it has left the nozzle rather than in the nozzle itself. This applies, of course, to that type of nozzle intended to be used with high pressure, either from the ground or from a ladder, since in this case it is necessary to have nozzles adapted to throw a certain distance in order to reach the foliage, and have it broken up into as fine a mist as possible. This does not apply to types of nozzles like the Vermorel and Friend, which are well adapted to the purposes for which they are intended.

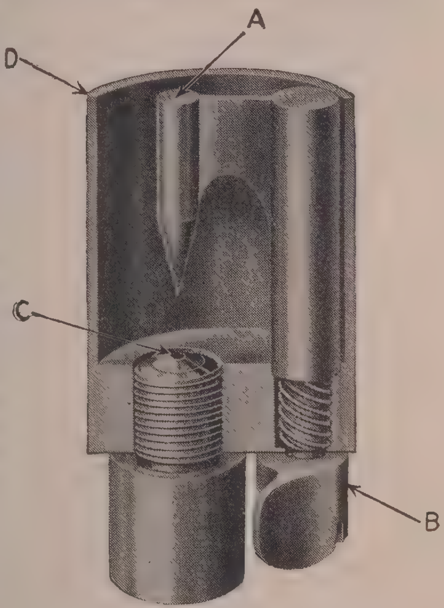

FIG. 109. — "M. A. C." nozzle. A, atomizing point or deflector; B, wing handle to adjust or swing point; C, nozzle proper; D, hollow case to protect A and C.

For high-pressure, solid-stream spraying in long-distance work, the Worthley tips are best. These tips range in size from one-eighth inch upwards, according to height of stream desired. They are constructed so as to break the stream into a mist at a certain height. With this type of nozzle the tops of trees can be sprayed most effectively, although the lower foliage does not receive so much of the spray. To overcome this difficulty the writer has devoted a great deal of time to experimenting with new types of nozzles, and from some forty or more designs two have been constructed which have given good results. One of these, known as

the "M. A. C. nozzle,"[1] has been patented and placed on the market. This nozzle is adapted for use with apertures ranging from one-eighth inch upwards, and is adjustable so that different types of sprays may be produced. It is designed for high-pressure work, and is more efficient at relatively close range than long distance; consequently, when used in connection with the Worthley tips an effective method of spraying results. With a three and one-half to six horse-power machine it can be used with one-eighth to three-sixteenths inch tips effectively, but in such cases a ladder must be employed with high trees.

The securing of competent men is also important in spraying. Any reliable man of common sense can learn to spray in a short time, and there should be little difficulty in securing such men if they are treated properly and well paid.

At the present time there are numerous types of spraying machines on the market ranging from two horse power on, and costing from $200 to $1,200. When it becomes necessary to spray a large number of trees in towns or cities, only the large size machine should be used, but the large machines are rather costly for small towns with a limited amount of work to be done.

In the case of towns having a limited amount of work to be done, it is better either to contract the work or secure a five or six horse-power machine. As a rule, contract spraying of shade trees, done with small hand pumps or with small machines, is quite unsatisfactory, the equipment not being adapted to the best work at the usual contract prices, especially when many large trees must be sprayed. The cost of spraying large trees with hand pumps or small machines with the Bordeaux nozzle should be at least $1.50 per tree, and few contractors take work at this price. When contracts are accepted at the price of 70 cents per tree the work must be slighted with the inferior equipment employed, and even then it is done at a loss. With the use of large machines and solid-stream sprays, city trees have been sprayed for about 20 cents each, and an average price in cities and towns would be from 20 to 39 cents. In one instance the average price for spraying about 900 elm trees, with an average diameter of 20 inches, during a period of six years was 57 cents per tree; a three and one-half horse-power engine and an "M. A. C. nozzle" were employed. Use was made of a ladder, but very little climbing was done, and the price represents the bare cost of material and labor. Deterioration of machinery, repairs, etc., are excluded. An outside contractor should of course receive considerably more for spraying to offset the extra items of expense, such as the cost of transportation, housing his men, etc.

[1] This nozzle was devised by the writer, and the patents are held by the Massachusetts Agricultural Experiment Station. It is manufactured and sold by Brackett, Shaw & Lunt, 62 North Washington Street, Boston, Mass.

Valuation of Shade Trees.

The valuation of shade trees is a very important question, and opinions on the subject often differ greatly. There are several different ways of arriving at the value of a shade tree, but in all of them the many factors modifying the value of a tree must be taken into consideration.

Since a tree planted for its shade, ornamental purposes, etc., possesses a utilitarian or property value, its real worth is usually represented by the cost of duplication. The amount of reduction in value of property from the loss of a tree is simply equivalent to the value of the tree, which in turn is represented by the amount it would cost to duplicate it. There is a limit to the size of tree that can successfully be transplanted, but it is possible to duplicate an 18-inch tree, and the value of trees that are too large to transplant may be estimated proportionately.

The transplanting of large trees is thoroughly practicable when done by men who understand it. A tree 6 inches in diameter may be moved for from $6 to $20, and one 14 inches in diameter for from $30 to $80, depending upon the availability of transplanting apparatus and of suitable trees.

Another method of determining the value of a tree, mentioned briefly above and often used in court, is to determine the decrease in value of the real estate affected by the loss of the tree, and expert appraisers of property are usually called in when this method is used.[1]

This method has its limitations, for real estate men are not necessarily familiar with all the factors affecting the value of a tree, — diseases, expectation of life, etc., which must be taken into consideration; consequently, they often set the value too high or too low. Moreover, the price per foot of real estate has little or nothing to do with the real value of a tree, which may be worth as much on a piece of property valued at $2,000 as on one valued at $6,000. As a matter of fact, the trees located on real estate have very little effect on the price obtained for the property, this depending much more upon the ability of the salesman. Then, too, while trees, shrubbery and other ornamental planting undoubtedly add value to property, it is a question whether the buyer often very seriously considers this fact when it comes to actually paying over his money. A tree is likely to be destroyed at any time by wind storms, lightning, etc., in which case it is impossible to recover damages, and it therefore does not appeal to the average buyer as a substantial property asset. Trees may be insured, but the writer's experience is that comparatively few persons regard trees as of sufficient value to warrant much expenditure. This is substantiated by the fact that in only a few cases, where trees have been destroyed by public-service corporations, and damages paid for them, have we observed any attempt to replace the dead trees

[1] Many trees attain to a diameter of at least 18 inches, and in many cases even more, in fifty years. Assuming that it costs $2 to plant a tree, and that it is worth $150 at this age and size when in good condition, the return on the original investment would be 9 per cent., compound interest.

with others of large size, and seldom even with small ones. Not infrequently the destruction of a tree is considered in the light of a blessing, although damages are always insisted on. It is almost invariably true that real estate owners who allow horses to disfigure their trees year after year, not showing enough interest to expend 75 cents or so for wire protection, usually insist on the heaviest damages when these same trees are destroyed by public-service corporations.

Another method of estimating the value of trees is by obtaining the cross-section area. Cross-section areas of trees are often obtained at a certain distance from the ground and the value computed at so much per square inch. The æsthetic features, location, species, imperfections, etc., are also taken into consideration in determining the value of the tree. This method may be used in deciding the value of trees too large to transplant, but even here some allowance should be made, since their utility, shade value, etc., do not increase proportionately with their increase in size.

There are many factors underlying the valuation of trees which should be, but seldom are, taken into consideration, and a short discussion of these follows: —

A tree may be valuable in more than one way. It may possess a *species* or *varietal* value, *i.e.*, it may be of a type possessing horticultural value for propagating purposes; it may possess *historic* value, such as the Washington elm and others; it may have merely a *sentimental* value, in being associated with some family event; or it may possess *æsthetic* value, from its landscape effect and intrinsic beauty; again, it may possess only a *timber* value, which in most cases is insignificant; and finally, it has a *utilitarian* or *property* value, which naturally includes many factors.

Other features which help to determine the value of a tree are as follows: —

Size. — Size is of importance in determining the value of a tree.

Form. — A tree may be of good size and of very poor shape. Unfortunately there are many trees which, on account of their poor shape, should never have been planted.

Vigor. — Shown by the rate of growth, size of leaves, color of foliage and condition of bark.

Susceptibility to Various Troubles, to Specific Diseases, etc. — These may follow as a result of the environment or may be peculiar to individuals.

Physical Condition. — Shown by freedom from cavities and wounds, caused by unscientific pruning and other mechanical agencies, — borers, various animals, etc.

Species. — The species is important also, not only from the standpoint of beauty but from its conformity to the environment, its longevity and susceptibility to disease. There are many species which were formerly of much greater value than they are to-day, owing to the increased number of troubles affecting them now, *e.g.*, the elm-leaf beetle, leopard moth, winter injury and drought.

Location. — If the importance of the location of a tree were better realized, much more accurate valuations would be given trees which have been destroyed. For instance, a tree located on a well-planted avenue is worth more than one growing on a poorly planted avenue.

A tree forming part of a symmetrical line of trees is, as a rule, of more value than one of an irregular group.

A tree planted too closely to others is of less value than one which has a chance to grow without restriction.

A tree located in a wide tree belt is worth more than one growing in a narrow tree belt.

A tree growing on a narrow avenue is of less value than one on a wide avenue, for in the latter case the water mains, sewers, etc., may be farther from the roots, which are less likely to become injured.

A tree growing inside the sidewalk is of more value than one growing on the edge of a road near the curbing, or in a ditch. Usually the farther from the roadbed the tree is located, at least in cities, the more valuable it is, for the roots are often amputated close to the trunk in street excavating, sidewalk and curbing construction, etc., and the tree is much more liable to injury from horses and trucks, runaways, etc.

A tree growing in a street where water mains, sewers, underground conduits and gas pipes are so numerous as to necessitate digging up the roadbed cannot have the value of one growing in an undisturbed roadbed.

A tree planted near manufacturing establishments or in other locations where it is subject to an atmosphere of smoke and various gases is also unfavorably located since its expectation of life is reduced.

A tree located where it is likely to become affected by sun scorch or drought is of less value than one growing under more normal conditions. Cultivated soil is better for a tree than a lawn, mowing or pavements, but next to cultivation the lawn conditions are most favorable. Abnormal chemical conditions of the soil and unsuitable soil texture affect growth and development. The location of a tree as regards distance and direction from a residence are important from the shade point of view.

Trees located close to oiled roadbeds are unfavorably situated, since the dust from oiled roads injures foliage. There is also a possibility of the roots themselves being affected by the oil.

On account of variation in their susceptibility to disease and to injury from climatic conditions, trees are often of more value in one location than another; for instance, those growing in country towns are usually under more wholesome conditions than those in cities. They may also be located in situations where certain pests thrive. While trees in cities are relatively short lived, they are considered of more value than town trees, because they serve a larger population.

The nature of the species and the conditions under which a tree is growing help to determine its expectation of life. An elm tree may live for two hundred to three hundred years in some localities, and in others sixty or seventy years is its limit, while the duration of life of other trees is even more restricted.

The extensive cutting of roots, made necessary by modern city street conditions, where business blocks with their deep foundations are often erected within a few feet of the highway trees, and where the placing of sidewalks, curbings and various other modern conveniences necessitate considerable excavating, renders even the most perfect specimen of tree almost worthless in a short time.

Court Decisions concerning Damages to Trees.

Of the many court decisions regarding the injury and death of trees, quite a few are valuable as precedents. It is too often the case that the official representatives of public-service corporations, which hold franchises granted by cities and towns, assume that the corporations have entire jurisdiction over everything interfering in any way with the operation of their systems. As regards this point may be quoted the decision of a justice of the Supreme Court, who stated that public-service corporations "have only such rights as others to the use of streets, and are subject therein at all times to reasonable regulation or even to termination at any time if the supreme authority acting in the public service shall so determine." He further maintains that "they have no rights of property in the streets, and their privileges are merely temporary ones, which may be recalled at any time and which carry with them no right of property whatever."

From a lack of understanding of or inability to conform to the law, and a disregard of the rights of the people, this often leads to friction between those having special care of trees and representatives of the corporations. The heads of corporations have always been better disposed toward public utilities than their representatives, and some of them have laid down stringent rules in regard to shade trees which their representatives are supposed to follow. Most States, however, recognize that trees located on public highways enhance the value of the abutter's property, and in case of the destruction of or injury to such trees, the abutter has the right to claim damages.

In a case decided by the Appellate Division, New York, an owner of land abutting on a city street, whose ownership did not extend to the middle of the street but "who had set out ornamental shade trees on the sidewalk in front of his premises at his own expense and with the sanction of the municipal authorities, is entitled to have such trees protected against negligent or willful destruction at the hands of third parties. He has a right in such trees in the nature of an equitable easement, and when one is girdled and destroyed by a horse, may recover from the owner of the horse the damages thus sustained."

In Minnesota an injunction was granted by the judge to restrain the defendant from cutting, mutilating or in any way damaging trees whose limbs were threatened by an old house that was being moved through the streets. Along the route which the building must take in the course of

moving were several shade trees which would have to be destroyed in order to move the building. The court maintained that "there can be no question of the right of plaintiff to the protection of the court to save these valuable trees from mutilation and possible destruction. The fact that these trees are in the street and not within the boundary line of plaintiff's premises does not alter in the least his right to have them protected, as they are his property. In the absence of proof to the contrary he is the owner of the land in front of his premises to the center of the street, subject only to an easement in the public to use it for the purposes of travel and the usual and ordinary incidents thereof. His rights of ownership yield only to the public welfare and convenience, and to the power of the municipal authorities to appropriately adapt the street and maintain it to meet the necessities of the travelling public."

From various court decisions it would appear that the value assigned to trees has sometimes been too high and often too low, and in the main, the extent of the damages resulting from the destruction of trees is based upon the deterioration occurring to the adjacent property. In general, it may be stated that a tree 18 or 20 inches in diameter, in good condition and in a desirable location, is worth $150, and a smaller one is of corresponding value. In private settlements, which are often made, for trees injured by public-service corporations, amounts ranging from $15 to $150 have been paid for trees of the above size, but in many cases from $40 to $100 is considered sufficient compensation for trees ranging from 10 to 18 inches in diameter, depending entirely, of course, upon the many factors that influence the value of a tree.

Several typical cases of court decisions concerning damages to trees follow: —

The jury of a circuit court in Missouri once awarded $200 against a telephone company for cutting out the top of a shade tree without consulting the owner. The tree in question was a 6-inch poplar which interfered with the telephone wires, and the workmen, without consulting the abutter, chopped out the top and center of the tree. The abutter sued for $300 and received $200.

A similar instance occurred in North Carolina, when an electric lighting company was sued for damages for cutting a tree on the edge of a sidewalk, even after being provided with the permission of the superintendent of streets, approved by the board of aldermen. The jury awarded the plaintiff a verdict of $499. Of course the case was appealed, but the judgment of the State Supreme Court was that while the city had the power under its charter to control streets and sidewalks and to remove obstructions when necessary, it did not, when it condemned land for highway purposes, acquire a title to it but merely a right of way over it, so that the plaintiff was still the owner of the tree.

In another case a resident of New York, owning residential property abutting on the city street, brought suit against a gas company for the destruction of trees by gas. The case involved the destruction of some

maple trees thirty-five years old, all in a thriving condition and furnishing good shade. Four of these trees were destroyed by the negligence of the gas company in permitting gas to escape from its pipes into the soil about the roots of the tree. Action was brought to recover the damages alleged to have been sustained by the plaintiff by reason of these facts, and the jury found a verdict in his favor for the sum of $150. Upon appeal to the Appellate Division, the judgment entered upon the verdict was unanimously confirmed. The court held, as a matter of law, that the plaintiff had a property right in these trees, although they were not planted upon lands to which he had a title.

The question of negligence in the destruction of shade trees is an important one, and opinions seem to differ as to what constitutes negligence. There are some cases in which negligence has not been established and decisions were rendered in favor of the defendants, although it should be pointed out that an appeal to the higher court often reversed such decisions. The case of Robbins *v.* the Hartford Gas Company, pertaining to the destruction by gas of shade trees located on the highway and on private property, resulted in a decision for the defendant, but on appeal to the higher courts the defendant made a satisfactory settlement with the plaintiff. In the case of Rooney *v.* the Hyde Park Gas Company, which involved a number of shade trees on the highway and on private property which were supposed to have been injured by gas, a decision was given in favor of the defendant. The gas leak as admitted by defendant occurred some distance away from the trees, and it was not established that they had been injured by gas, neither could negligence be established.

These cases concern action brought by property owners against public-service corporations for the destruction of trees, but in accordance with our Massachusetts statutes city foresters or tree wardens can bring action for injury or destruction to shade trees located on the public highway. For instance, the city forester of Springfield brought suit against the Springfield Gas Company for the destruction of sixty shade trees, and the judge rendered a verdict in favor of the defendant, since negligence was not established. The gas company, however, made no attempt to establish any case; moreover, they had previously settled with the owners of the adjacent property for many of the trees involved, thereby acknowledging in such settlement that the trees had been killed by gas.

In another case the town of Athol brought suit through the tree warden against the Athol Gas Company for killing public shade trees by gas. The decision given by the judge of the local court was in favor of the plaintiff. The gas company appealed, but again lost its case before a jury in the higher court. In the case of the Superintendent of Parks, Lowell, *v.* the Lowell Gas Company, in which some fifty trees were supposedly killed by gas, a fine of $900 was imposed on the company in the police court, the same being paid to the city treasurer. In addition to the fine, the gas company settled with many of the abutters.

A few years ago fifteen tupelo trees were cut on private land by an

electric railway company. The court awarded triple damages on the ground that the cutting was willful, and the company was fined $1,200.

A case is recorded of a superintendent of an electric light company being adjudged guilty in a Massachusetts court on a charge of injuring and destroying shade trees on the highway. The court imposed a fine of $25. In another case a lineman was fined $15 in the district court on complaint of a tree warden for climbing trees with spurs.

Innumerable other court cases could be cited similar to those already given illustrating the laws in regard to public shade trees. In some States, however, according to decisions of the courts, public shade trees may be destroyed from almost any cause without any compensation to the adjacent property owner. By far the larger number of cases of injury to and destruction of shade trees from various causes never reach the courts, and it is much better to arrive at some satisfactory settlement by arbitration than to resort to criminal proceedings. One Massachusetts city, however, has attempted to require a public-service corporation to give a bond for the payment of damages to trees, but this regulation was not adopted by the aldermen of the city.

There are only a few instances, to my knowledge, of the courts awarding damages for trees supposed to be killed by electricity. Most courts would undoubtedly allow damages for serious burnings brought about by wires, but there are only a small number of cases in which electricity has actually killed a tree and in these cases the death of the tree was due to a reversed polarity in the electric railways.[1]

Codified Shade Tree Laws of Massachusetts, 1915.

For several years prior to 1899 there was a provision in the Massachusetts statutes that towns might elect tree wardens. By the acts of that year it was provided that every town must elect a tree warden, and the duties and powers of the office were defined. The tree warden law of 1899, with certain amendments in details, remains in force to-day and regulates the care of shade trees in every town in the Commonwealth.

Chapter 145, General Acts of 1915.

Section 1. The powers and duties conferred and imposed upon tree wardens in towns by this act are hereby conferred and imposed upon the officials now or hereafter charged with the care of shade trees within the limits of the highway in cities, by the charters of the said cities, by other legislative enactments, or by the ordinances of the said cities, and upon such officials as the city governments shall designate to have charge of said shade trees where it is within their power to transfer such duties, by ordinance or otherwise.

Section 2. The tree warden may appoint and remove deputy tree wardens. He and they shall receive such compensation as the town determines or, in default thereof, as the selectmen allow. He shall have the care and control of all public shade trees, shrubs and growths in the town, except those within the limits of a

[1] Electrical Injuries to Trees, Mass. Agr. Exp. Sta. Bul. 156, 1914.

state highway, and except those in public parks or open places under the jurisdiction of the park commissioners, and of those, if so requested in writing by the park commissioners, and shall enforce all the provisions of law for the preservation of such trees, shrubs and growths. He shall expend all money appropriated for the setting out and maintenance of such trees, shrubs and growths, but no trees shall be planted within the limits of a public way without the approval of the tree warden; and in towns until a location therefor has been obtained from the selectmen or road commissioners, where authority has been vested in said commissioners. Regulations, other than those made by the terms of this act, for the care and preservation of public shade trees made by him, and in towns approved by the selectmen, and posted in two or more public places, imposing fines and forfeitures of not more than twenty dollars in any one case, shall have the force and effect of town by-laws. All trees within or on the limits of a public way shall be public shade trees; and when it appears in any proceeding where the ownership of or rights in the tree are material to the issue, that, from length of time or otherwise, the boundaries of the highway cannot be made certain by the records or by monuments, and that for that reason it is doubtful whether the tree be within or without the limits of the highway, or is public or private property, it shall be taken to be within the limits of the highway and to be public property until the contrary is shown.

SECTION 3. Except as provided by section five, public shade trees shall not be cut, trimmed or removed, in whole or in part, by any person other than the tree warden or his deputy, whether such person is or is not the owner of the fee in the land on which such tree is situated, except upon a permit in writing from said tree warden, nor shall they be cut down or removed by the tree warden or his deputy or other person without a public hearing at a suitable time and place, after notice thereof posted in two or more public places in the town or city and upon the tree at least seven days before such hearing, and after authority granted by the tree warden therefor: *provided, however*, that if the tree warden shall refuse to cut or remove or issue a permit to any such owner to cut or remove any such tree or other growth, the damages, if any, sustained by him shall be determined in towns by the selectmen and in cities by the officer or officers in charge of the public shade trees and shall be paid by the town or city. Any person aggrieved by the action of the selectmen or said officer or officers in charge of the public shade trees as to the trimming, cutting, removal or retention of any such tree, or as to the amount awarded to him for the same may have the damages, if any, which he has sustained, determined by the superior court for the county in which the said tree is or was situated, upon a petition filed for the purpose, in the same manner as for the taking of land for ways; and his damages, so determined, shall be paid by the town or city,

SECTION 4. Tree wardens shall not cut down or remove or grant a permit for the cutting down or removal of a public shade tree if, at or before a public hearing as provided in the preceding section, objection in writing is made by one or more persons, unless such cutting or removal or permit to cut or remove is approved by the selectmen or by the mayor.

SECTION 5. Tree wardens and their deputies, but no other person, may, without a hearing, trim, cut down or remove trees, under one and one half inches in diameter one foot from the ground, and bushes, standing in highways; and, if ordered by the mayor and aldermen, selectmen, road commissioners or highway surveyor, shall trim or cut down trees and bushes, if the same shall be deemed to obstruct, endanger, hinder, or incommode persons travelling thereon. Nothing contained in this act shall prevent the trimming, cutting or removal of any tree which endangers persons travelling on a highway, nor the removal of any tree, if so ordered by the proper officials, for the purpose of widening the highway, and nothing herein contained shall interfere with gypsy and brown tail moth suppression, as carried on under the direction of the state forester and the United States department of agriculture, except the cutting and removal of trees, shrubs and growths that are one and one half inches or more in diameter one foot from the ground.

SECTION 6. Whoever violates any of the provisions of the preceding sections of this act shall forfeit not more than five hundred dollars to the use of the town or city.

SECTION 7. Towns and cities may appropriate money to be expended by the tree warden in planting shade trees in the public ways, or, if he deems it expedient, upon adjoining land, at a distance not exceeding twenty feet from said public ways for the purpose of improving, protecting, shading or ornamenting the same: *provided, however*, that the written consent of the owner of such adjoining land shall first be obtained.

SECTION 8. The Massachusetts highway commission shall have the care and control of all trees, shrubs and growths within the limits of state highways, and may trim, cut or remove such trees, shrubs and growths, or license the trimming, cutting or removal thereof. No such tree, shrub or other growth shall be trimmed, cut or removed by any person other than an agent or employee of the commission, whether such person is or is not the owner of the fee in the land on which such tree, shrub or growth is situated, except upon a permit in writing from said commission: *provided, however*, that if the commission shall refuse to issue a permit to any such owner to cut or remove any such tree, shrub, or other growth, the damages, if any, sustained by him shall be determined by said commission and paid by the commonwealth. Any person aggrieved by the action of the commission as to the trimming, cutting, removal or retention of any such tree, shrub or other growth, or as to the amount awarded to him for the same by the commission, may have the damages, if any, which he has sustained, determined by the superior court for the county in which the said tree, shrub or other growth is or was situated, upon a petition filed for the purpose, in the same manner as for the taking of land for highways, and his damages, so determined, shall be paid by the commonwealth.

SECTION 9. Whoever affixes to a tree in a public way or place a play bill, picture, announcement, notice, sign, advertisement or other thing, whether in writing or otherwise, or cuts, paints or marks such tree, except for the purpose of protecting it or the public and under a written permit from the officer having the charge of such trees in a city or from the tree warden in a town, or from the Massachusetts highway commission in the case of a state highway, shall be punished by a fine of not more than fifty dollars for each offence. Tree wardens shall enforce the provisions of this section: *provided, however*, that in case of the failure of a tree warden to act in the case of a state highway within thirty days after the receipt by him of a complaint in writing from the Massachusetts highway commission, said commission may proceed to enforce the provisions of this section.

SECTION 10. Whoever without authority trims, cuts down or removes a tree, shrub or growth, within the limits of a state highway or maliciously injures, defaces or destroys any such tree, shrub or growth shall be punished by imprisonment for not more than six months or by a fine of not more than five hundred dollars, to the use of the commonwealth.

SECTION 11. Whoever, wilfully, maliciously, or wantonly cuts, destroys or injures a tree, shrub or growth, which is not his own, standing for any useful purpose, shall be punished by imprisonment for not more than six months or by a fine of not more than five hundred dollars.

SECTION 12. Whoever wantonly injures, defaces, or destroys a shrub, plant or tree, or fixture of ornament or utility, in a public way or place or in any inclosure, or negligently or wilfully suffers an animal driven by or for him or belonging to him to injure, deface or destroy, such shrub, plant, tree or fixture, or whoever by any other means negligently or wilfully injures, defaces, or destroys such shrub, plant or tree, or fixture, shall forfeit not more than five hundred dollars, one half to the use of the complainant and one half to the use of the city or town in which the act was committed; and shall in addition thereto be liable to said city or town or other person interested in said tree for all damages caused by such act.

SECTION 13. Section fifteen of chapter twenty-five of the Revised Laws, in so far as it relates to trees; section ten of chapter fifty-one of the Revised Laws, in so far as it gives authority over trees and bushes; sections one hundred and one, one hundred and two and one hundred and four of chapter two hundred and eight of the Revised Laws, as amended by sections thirty-one and thirty-two of chapter five hundred and forty-four of the acts of the year nineteen hundred and two; section twelve of chapter fifty-three of the Revised Laws, as amended by section two of chapter two hundred and ninety-six of the acts of the year nineteen hundred and eight and by chapter three hundred and twenty-one of the acts of the year nineteen hundred and ten; section thirteen of chapter fifty-three of the Revised Laws, as amended by section three of chapter two hundred and ninety-six of the acts of the year nineteen hundred and eight; section sixteen of chapter twenty-five of the Revised Laws; section one of chapter three hundred and sixty-three of the acts of the year nineteen hundred and ten; and chapter two hundred and seventy-nine of the acts of the year nineteen hundred and five, as amended by chapter two hundred and ninety-seven of the acts of the year nineteen hundred and eight, are hereby repealed.

SECTION 14. The provisions of this act, so far as they are the same as those of existing statutes, shall be construed as continuations thereof and not as new enactments.

SECTION 15. This act shall take effect upon its passage. [*Approved April 7 1915.*

R. L., CHAPTER 208, SECTION 115.

LAW REGARDING THE POSTING OF NOTICES, ETC., WITHIN THE LIMITS OF THE HIGHWAY.

Whoever paints, or puts upon, or in any manner affixes to, any fence, structure, pole, rock or other object which is the property of another, whether within or without the limits of the highway, any words, device, trade mark, advertisement or notice which is not required by law to be posted thereon, without first obtaining the written consent of the owner or tenant of such property, shall, upon complaint of such owner, or of his tenant, or of any municipal or public officer, be punished by a fine of not more than ten dollars. Any word, device, trade mark, advertisement or notice which has been painted, put up or affixed within the limits of a highway in violation of the provisions of this section shall be considered a public nuisance, and may be forthwith removed or obliterated and abated by any person.